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# LYRIELASMA AND A NEW RELATED GENUS OF DEVONIAN TETRACORALS

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## Abstract

The type species of *Lyrielsma* and six related species from the Lower Devonian of SE. Australia are described and figured. Subspecies are recognized in three of these and a variety in another. The generic concept of *Lyrielsma* is conserved by referring to it only species having a peripheral stereozone containing an appreciable amount of lamellar sclerenchyme. Similar fasciculate species lacking such a stereozone are placed in a new genus *Embolophyllum*. As originally named the type species of *Lyrielsma* was a junior primary homonym; a new name therefore is proposed for it. Systematically treated taxa are: *Lyrielsma chapmani* nom. nov., *L. chapmani praecursor* Philip, *L. sp. nov.*, cf. *L. chapmani* nom. nov., *Embolophyllum asper* (Hill), *E. aggregatum aggregatum* (Hill), *E. aggregatum cracente* subsp. nov., *E. aequiseptatum aequiseptatum* (Hill), *E. aequiseptatum buehanense* subsp. nov., *E. mundum* sp. nov., *E. (?) mansfieldense* (Dun), *E. (?) mansfieldense* var. *fecundum* nov.

## Introduction

The type species of *Acanthophyllum* and *Grypophyllum* have been redescribed in recent years. However, apart from the erection of a new subspecies, the type species of the closely related genus *Lyrielsma*, has received only scant attention.

Presentation of a new description and figures of this species, based on abundant topotypes now available, is one of the objects of the present paper, but the main purpose is to demonstrate that certain Australian species, previously supposed to be solitary and placed in *Acanthophyllum*, are in fact fasciculate and generically identical with other species referred to *Lyrielsma* or *Grypophyllum*. For various reasons these species cannot be placed in any of these, or indeed, other described genera, and therefore a new genus, named *Embolophyllum*, is proposed for their reception.

Localities providing the corals described are shown in Fig. 1. While the stratigraphical nomenclature employed for the Victorian sequences is entirely conventional, the nomenclature used for the Wee Jasper area is new, at least as far as the particular area is concerned. A detailed biostratigraphical account of the Wee Jasper area is in preparation and will show an overall similarity between the Taemas-Cavan and Wee Jasper limestone successions. In view of this the broad stratigraphical divisions originally proposed for the Taemas-Cavan area are equally applicable in the Wee Jasper area.

Some of the evidence for the ages ascribed to the species has been published by Philip and Pedder (1964) and Philip (1965), but again, more detailed arguments are either at press or in preparation.

I am grateful to E. D. Gill and T. A. Darragh for making available specimens in their care at the National Museum of Victoria. I also wish to express my thanks to W. A. Oliver of the U.S. Geological Survey, Washington, for information concern-

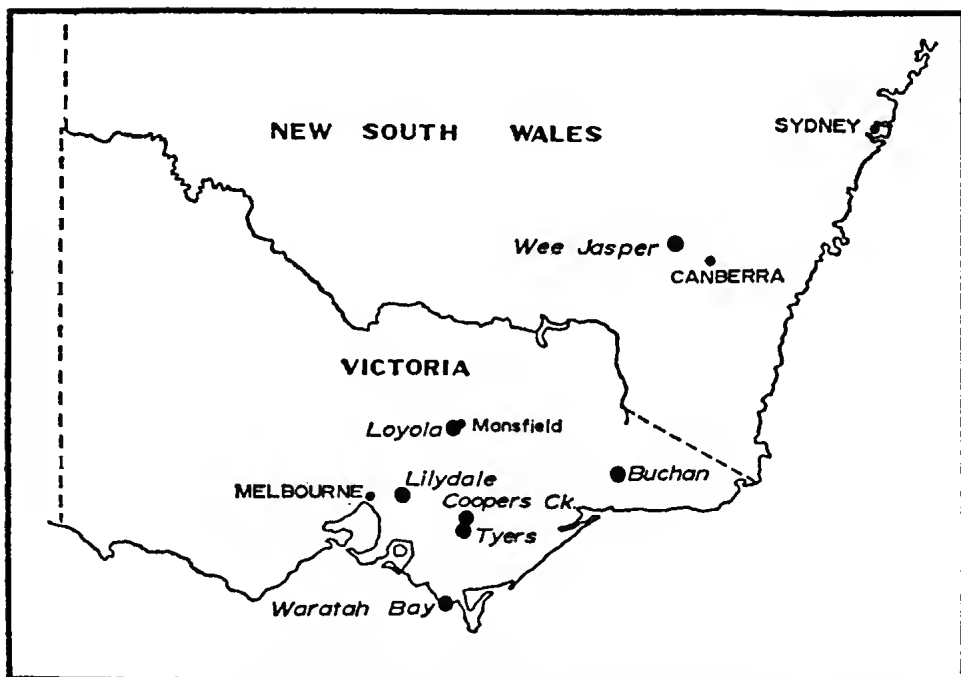


FIG. 1—Map of Vict. and part of N.S.W. Localities of corals described in the text are indicated by the larger circles.

ing the genus *Enterolasma*, and to D. L. Strusz of the University College of Townsville, for sending the manuscript of a paper describing the Spongophyllidae of the Garra Beds. B. R. Whan, of the technical staff of the University of New England's Geology Department drafted the scatter diagrams and photographed the other text-figures, and N. Petrasz of the same staff, assisted in the preparation of the thin sections. Most of the material used in the paper was collected in company with either G. M. Philip or J. H. Jackson, during field-work made financially possible by the University of New England's Research Grant No. 120.

### Systematic Descriptions

Fossil collections referred to are abbreviated as follows:

- AM—Australian Museum, Sydney
- GSV—Geological Survey of Victoria, Melbourne
- NMV—National Museum of Victoria, Melbourne
- UM—University of Melbourne
- UNE—University of New England, Armidale
- UQ—University of Queensland, Brisbane.

### Family SPONGOPHYLLIDAE Dybowski

#### Genus *Lyrielasma* Hill

1939 *Lyrielasma* Hill, p. 243, 244.

?1950 *Lyrielasma*, Wang, p. 224.

?1960 *Lyrielasma*, Oliver, p. 8, 10.

1962 *Lyrielasma*, Soshkina and Dobrolyubova in Orlov, p. 335.



TYPE SPECIES: *Cyathophyllum caespitosum* Chapman, redescribed below as *Lyriellasma chapmani* nom. nov.

DIAGNOSIS: Solitary (?) to fasciculate corallum with subcylindrical corallites; budding where observed, peripheral and non-paricidal. Peripheral stereozone prominent and in part composed of lamellar sclerenchyme; internal lamellar stereozones may also be present. Septa well developed, either radially or pinnately arranged, strongly carinate in early stages, later becoming less carinate or even smooth. Trabeculae parallel and more or less horizontal. Dissepiments elongate, steeply inclined and rarely lonsdaleoid; rare or absent in early stages, normally several deep in adult stages. Tabularium axially depressed, composed of predominantly closely spaced and incomplete tabulae.

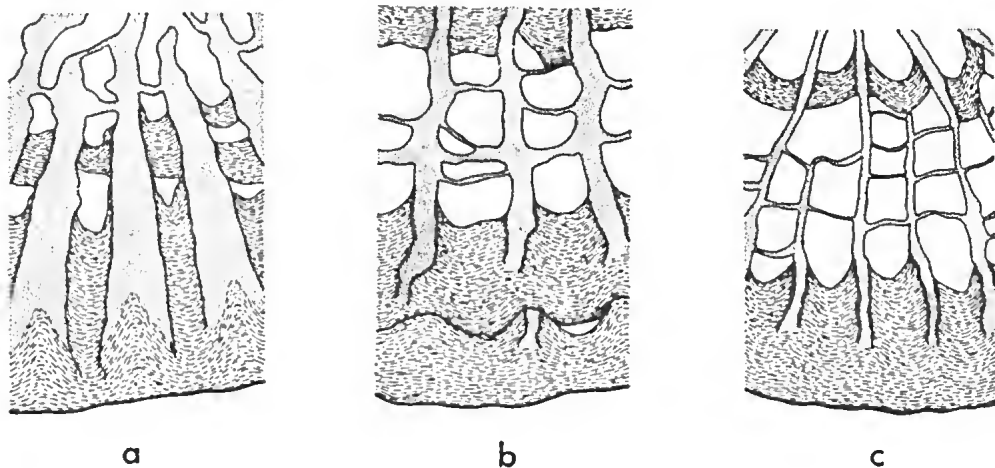


FIG. 2—*Lyriellasma* spp.,  $\times 16$ . Semidiagrammatic figures of transverse sections showing the relationship between the septa (stippled) and the peripheral lamellar stereome. (a) *Lyriellasma chapmani* nom. nov., UNE F8862, hypotype, Lilydale Limestone, Cave Hill, Lilydale, Viet.; (b) *Lyriellasma chapmani* nom. nov., UNE F8866, hypotype, same locality; (c) *Lyriellasma* sp. nov. cf. *L. chapmani* nom. nov., UNE F8933, hypotype, Coopers Creek Formation, Evans Brothers' Quarry, Coopers Creek, Viet.

REMARKS: Young individuals of *Lyriellasma* resemble *Enterolasma* Simpson (1900, p. 203-205) and *Cymatelasma* Hill and Butler (1936, p. 516, 517). However the resemblance diminishes as dissepiments are added during ontogeny.

*Lyriellasma* shares many features with *Grypophyllum* Wedekind (1922, p. 13), and serious consideration must be given to the question of whether it is, like *Hooeiphyllum* Taylor (1951, p. 173, 174), a junior synonym of Wedekind's genus. The literature at the writer's disposal shows that there are at least 37 species and varieties either originally described as *Grypophyllum*, or later transferred to it. Although most of these are spongophyllids, the total includes stringophyllids, bethanyphyllids, an endophyllid and a digonophyllid. The spongophyllids of this total, range in age through part of the Lower, to late Middle Devonian; there is much variation in their morphology and it seems probable that they can be successfully fragmented into shorter ranged genera.

*Grypophyllum aggregatum* Hill becomes part of the new genus *Embolophyllum* and perhaps some of the specimens currently referred to *Grypophyllum striatum*

would rest more easily in the same genus. Other species that should be excluded from *Grypophyllum* are: *G. carinatum* (Soshkina 1936, p. 60-62, 74, fig. 68-70; 1949, p. 133-135, Pl. 52, fig. 3-8; Pl. 53, fig. 1-4; 1952, p. 96, Pl. 34, fig. 118), *G. gorskyi* Bulvanker (1934, p. 11-13, Pl. 5, fig. 4, 5; Soshkina 1949, p. 133, Pl. 44, fig. 5a, b; 1952, p. 95, 96, Fig. 89), both from the Givetian of the Urals, and *G. sailairicum* Bulvanker (1958, p. 145, 146, Pl. 51, fig. 1a-2) from the Eifelian of the Kuznetsk Basin. These are small solitary corals, and unlike *Grypophyllum*, *sensu stricto*, possess flanged septa.

From the species retained in *Grypophyllum* for the purposes of the present paper, two distinct species groups emerge. The more typical, that is the one including the type species *G. denckmanni* Wedekind (1922, p. 13-15, Fig. 13, 14), embraces about ten described species, known mainly from the Givetian of Europe and Asia. It consists of solitary (Engel and Schouppé 1958, p. 104) and weakly fasciculate corals (Middleton 1959, Fig. 4c) having steeply sloping calicular walls, thin smooth septa embedded peripherally in a moderately thick lamellar wall, and closely spaced, flat to axially depressed tabulae; the dissepimentarium is relatively broad and due to suppression of minor septa, may be of the herringbone type.

Another closely related species group centres around *Cyathophyllum vermiculare* Goldfuss (1826, p. 54, Pl. 17, fig. 4). Corals of this group are distributed from France to the Urals, particularly in Middle Devonian beds, and differ from species such as *G. denckmanni* in having a relatively thinner wall, more consistently developed minor septa and apparently an invariably solitary corallum. The genera *Stenophyllum* Wedekind (1925, p. 9, 10) and *Leptoinophyllum* Wedekind (1925, p. 4) are based on species of this group. The first is preoccupied by a myriapod (Verhoeff 1897, p. 122), the other is available if required, but has been merged in *Grypophyllum* by Birenheide (1961, p. 114).

Other species currently held in *Grypophyllum* deviate from the typical morphology in several ways. *G. compactum* Hill (1942a, p. 255, 256, Pl. 10, fig. 1-4) from the Givetian of Queensland and *G. graciliseptatum* Pedder (1964, p. 441-443, Pl. 67, fig. 1-19) from late Eifelian or early Givetian beds of western Canada may have axially elevated tabulae. *G. cornus* McLaren (in McLaren and Norris 1964, p. 10, 11, Pl. 3, fig. 3) a Givetian coral, also from western Canada, has an apparently thin wall, irregular septa and widely spaced tabulae. Another variation is seen in *G. gracile* var. *kuznetskiense* Bulvanker (1958, p. 145, Pl. 31, fig. 1, 2), from the Givetian of the Kuznetsk Basin; in this variety the dissepiments are extremely large, and despite the brevity of the minor septa, the dissepimentarium is not of the herringbone type.

A comparison of text-figures, prepared from the best Victorian material of *Lyrielsma*, with others drawn from Chinese specimens identified as *Grypophyllum* (Wang 1950, Pl. 7, fig. 56), suggests that there is no fundamental difference between the genera, in either the wall, which is lamellar, or the septa, which are embedded in it. However, the wall is proportionately thicker in *Lyrielsma* and the genera are further distinguished by the development of flanged septa in *Lyrielsma*, at least in early stages.

*Fasciphyllum petshoreense* described by Soshkina (1949, p. 110, 111, Pl. 44, fig. 1-4; 1952, p. 97, Pl. 37, fig. 128) from the Emsian of the Urals is a species of *Lyrielsma*. Glinkski (1957, p. 97) contends that *Fasciphyllum* Schlüter (1885, p. 52) is a synonym of *Battersbyia* Milne-Edwards and Haime (1851, p. 151, 227), but in any case these genera have a narrower dissepimentarium and septa without flanges.

Definite occurrences of *Lyriellasma* are presently restricted to the late Gedinnian or Siegenian of Victoria (see below), Emsian of N.S.W. (*L. floriforme* Hill 1942b, p. 146, 147, Pl. 2, fig. 2), and the Emsian (see above) and Eifelian (see below) of the Urals. However, as Hill (1939, p. 245) noted, there are reasons to believe that the genus may also be represented in the Emsian of France (*Cyathophyllum dianthus* and *C. elongatum* Le Maître 1934, p. 152-154, Pl. 5, fig. 10-14; Pl. 18, fig. 7) and the Carnic Alps (*C. dianthus*, *sensu* Charlesworth 1914, Pl. 31, fig. 8). Other possible occurrences are in the late Gedinnian (?) Beck Pond Limestone of northern Maine (*L. annulatum* Oliver 1960, p. 10-12, Pl. 2, fig. 1-6; Pl. 3, fig. 1-5) and the Emsian (?) Malobachatskie Beds of the Sayano-Altai region of Siberia (*L. denticulata* Zheltonogova in Khalfina 1961, p. 379, Pl. D35, fig. 4). A septal stereozone is stated to be present in both the last named species, but descriptions make no mention of lamellar sclerenchyme.

Hill (1939, p. 245) drew attention to the similarity between *Lyriellasma* and certain Middle Devonian corals from the Eifel. Although two of the latter were later figured and unequivocally identified as *Lyriellasma* by Wang (1950, Pl. 7, fig. 57; Pl. 9, fig. 75), they are here excluded from the genus because of the absence of a peripheral stereozone. They may be solitary, and if so would be congeneric with species such as '*Grypophyllum*' *carinatum*, discussed earlier in these remarks. *Lyriellasma sperabile* Crickmay (1962, p. 5, Pl. 1, fig. 7; Pl. 3, fig. 1-3) from sub-surface Givetian beds in western Canada, is also excluded from the genus; it has a thin wall, virtually or entirely smooth septa, and in spite of the axial elevation of the tabulae is probably close to *Grypophyllum*.

#### *Lyriellasma chapmani* nom. nov.

The original name *Cyathophyllum subcaespitosum* is a junior primary homonym of *C. subcaespitosum* Meek (1873 and in King 1877) and must be rejected (I.C.Z.N. Articles 59, 60). It is therefore proposed that the trivial name be replaced by *chapmani*, in honour of the original author of the Victorian species, Frederick Chapman.

Previous literature records the species in limestones at Lilydale, Loyola, Tyers R. and questionably from Waratah Bay. However, differences have been noted between the holotype and most other topotypes from Lilydale, and also between the holotype and specimens from Loyola, Tyers R. and Waratah Bay.

Although recent field-work has added to the existing collections from all these localities, there is still too little material for final settlement of the precise taxonomy of the species. The view adopted tentatively for the present work is that the specimens from Lilydale, Waratah Bay and perhaps Loyola, pertain to the nominate subspecies, while a distinct subspecies, previously named *praecursor*, is represented by the specimens from Tyers R.

#### *Lyriellasma chapmani chapmani* nom. nov.

(Pl. 1, fig. 1-14; Pl. 2, fig. 1-9; Fig. 2a, b, 3a-4)

- 1925 *Cyathophyllum subcaespitosum* Chapman, p. 112, Pl. 13, fig. 15-16b.
- 1939 *Lyriellasma subcaespitosum* (Chapman), Hill, p. 244-246, Pl. 14, fig. 1-6; Pl. 15, fig. 6, 7.
- 1949 *Lyriellasma subcaespitosum* (Chapman), Stumm, p. 34, Pl. 16, fig. 3-5.
- 1954 *Lyriellasma* ? *subcaespitosum* (Chapman), Hill, p. 111, Pl. 7, fig. 14a, b.
- 1956 *Lyriellasma subcaespitosum* (Chapman), Hill in Moore, p. 306, fig. 208, 1a-c.
- 1962 *Lyriellasma subcaespitosum* (Chapman), Phillip, p. 188, Pl. 28, fig. 6, 7.
- non 1873 *Cyathophyllum subcaespitosum* Meek, p. 470 (= *Dorlodotia subcaespitosa*, see Sando 1965, p. 11-15, Pl. 4).

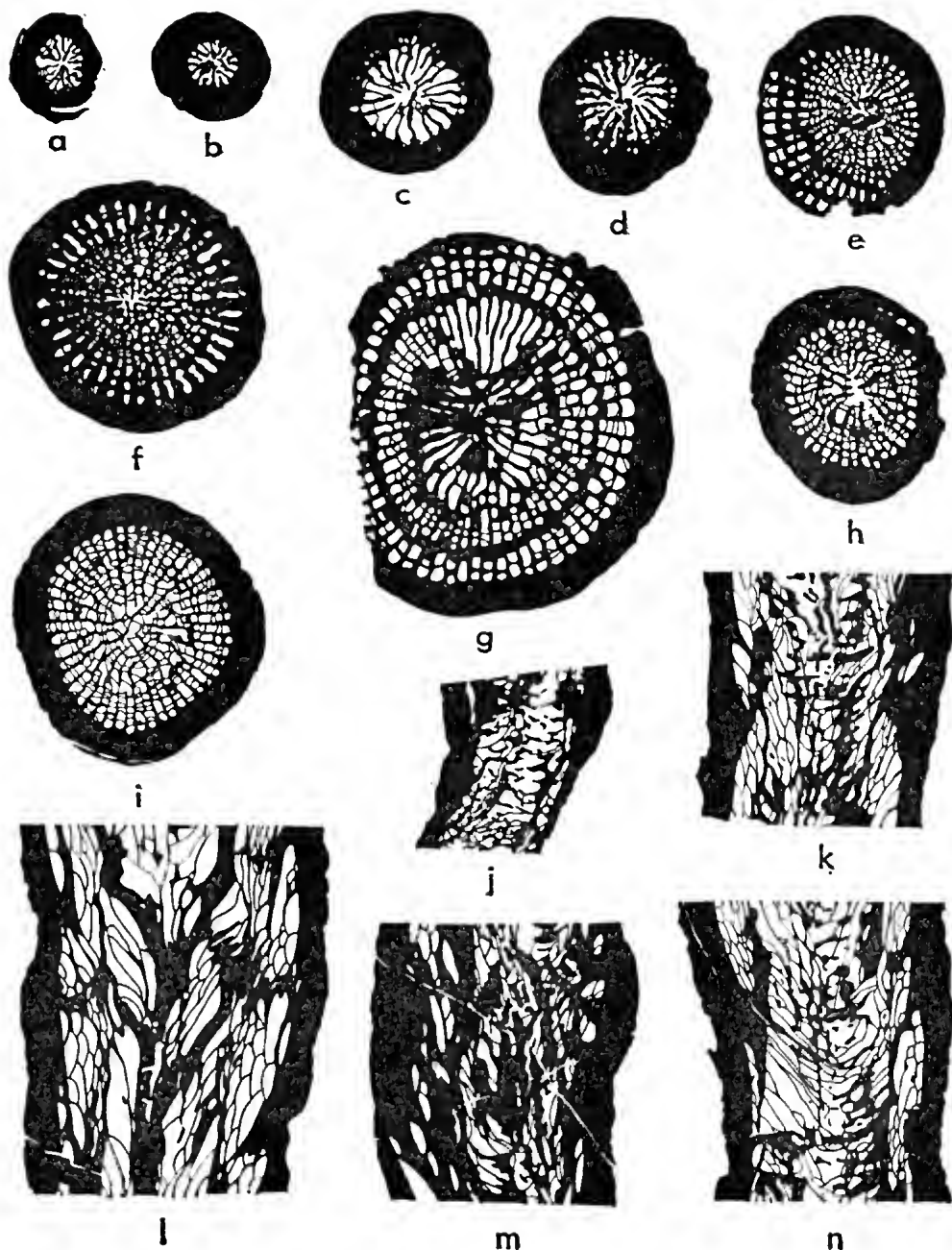


FIG. 3.—*Lyriellasma chapmani chapmani* nom. nov.,  $\times 3$ . Hypotypes from the Lilydale Limestone at Cave Hill, Lilydale, Vict. Fig. a-i are transverse sections and j-n longitudinal sections. (a) UNE F8877; (b) UNE F8874; (c) UNE F8876; (d) UNE F8867; (e) UNE F8861; (f) UNE F8871; (g) UNE F8866; (h) NMV P23013; (i) UNE F8865; (j) NMV P23009; (k) NMV P23013; (l) UNE F8863; (m) UNE F8862; (n) UNE F8865.

- non 1877 *Cyathophyllum subcaespitosum* Meek, Meek in King, p. 60, 61, Pl. 5, fig. 4-4b  
(= *Orygmophyllum* (?) *whitneyi*, see Sando 1965, p. 17, Pl. 6, fig. 6-11).  
Pl. 19, fig. 4a, b.
- non ? 1962 *Lyrielasma subcaespitosum* (Chapman), Soshkina and Dobrolyubova in Orlov,  
Pl. 19, fig. 4a, b.

**MATERIAL:** Records at the National Museum of Victoria indicate that the holotype is now in six parts; four of these are thin sections, catalogued P15969-P15972, and two are hand specimens, numbered P1731 and P14065. During a visit to the Museum in March, 1965, thin sections P15970-P15972 only could be found. The paratype, NMV P13303, has not been sectioned, and like parts of the holotype could not be found in March, 1965. Both specimens were collected by A. W. Cresswell from the Lilydale Limestone (Siegenian) at Cave Hill, Lilydale, Vict.

In addition to the type series there are 29 topotypes, registered as follows: AM F1329a, b (two specimens), collectors unrecorded; UM TS1628, TS1629 (same specimen), TS1630-TS1632 (another specimen), both collected by G. M. Philip; NMV P22996, P23006, P23009, P23013, P23016, P23018, collectors unrecorded; UNE F8859-F8864, collected by G. M. Philip and the writer; UNE F8865-F8877, collected by the writer.

Other hypotypes include two specimens collected by Curt Teichert from the Kiln Member (Siegenian) of the Waratah Limestone at Waratah Bay, Vict. and a specimen collected by A. N. Carter from the Bird Rock Member (Siegenian) of the same formation. These specimens were studied by Hill and the one collected by Carter is now registered UQ F17101; Teichert's material was returned to the University of Melbourne in 1953, but at the time of writing has yet to be catalogued.

Two other hypotypes, UM TS621, TS622 (same specimen) and UNE F8878, are from the Loyola Limestone (Siegenian) at Griffith's Quarry, Loyola, near Mansfield, Vict. The first was collected by E. A. Ripper and the second by the writer.

**DIAGNOSIS:** Corallum fasciculate, perhaps in some cases solitary; increase, where known, peripheral; mean diameter of adult corallites not exceeding 16 mm, typically 6 to 12 mm. Calice with steep sides and deep central depression. Wall partly lamellar, normal thickness 1.2 to 1.5 mm, maximum 3.0 mm;  $18 \times 2$  to  $30 \times 2$  septa per adult corallite. Trabeculae horizontal. In early stages septa strongly flanged, dissepiments and tabulae few or absent. In later stages septa less flanged, dissepiments up to 7 or 8 deep, tabulae numerous and deeply depressed at the axis.

**DESCRIPTION:** While some specimens from Lilydale are fasciculate and others almost cerioid, most are apparently single corallites. This is largely and perhaps entirely due to post mortem damage, which characterizes many of the fossils from the Lilydale Limestone. Non-paricidal peripheral budding has been observed in one specimen (Philip 1962, Pl. 28, fig. 6). Individual corallites are initially ceratoid, subsequently subcylindrical, and may be elliptical or oval, rather than circular in transverse section; rejuvenescence occurred from time to time. Although the maximum mean diameter is 16 mm, most corallites are 12 mm or less in diameter. Periodic layers of sclerenchyme show that the calice was steep sided and in some cases exceptionally depressed at the centre.

In corallites of less than 5 mm or so diameter, the marginarium consists almost exclusively of a partly septal and partly lamellar stereozone, with a width equivalent to approximately one-half the radius of the corallite. In larger corallites the width may increase to 3.0 mm, but more usually remains about 1.2 to 1.5 mm; thus relatively the thickness decreases during ontogeny.

Septa radial, or less commonly, pinnate in arrangement. At first the major are strongly flanged and the minor may be confined to the stereozone. Later the flanges

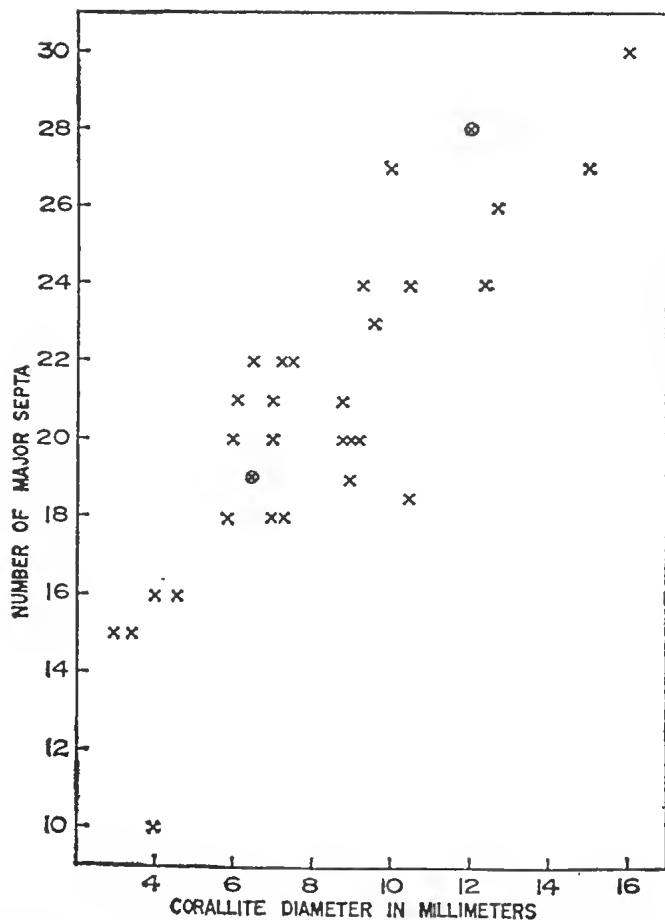


FIG. 4.—*Lyriellasma chapmani chapmani* nom. nov. Scatter diagram of number of major septa  $\times$  diameter in 27 specimens from the type locality. Points derived from the holotype are encircled.

are generally less pronounced and in some case entirely lost, and the minor septa increase to between one-half and three-fifths of the length of the major, which terminate near the axis. The cardinal and counter septa are variably developed, one or both may be longer than other major septa. Septal counts at various diameters are given in Fig. 4. Trabeculae are essentially parallel, and although flexed in places, are directed more or less horizontally towards the axis.

Dissepiments develop slowly during ontogeny; corallites of less than 5 mm diameter rarely possess more than a few, and may be quite devoid of them. At 10 mm diameter there are approximately 4 or 5 rows and in the largest corallites 7 or 8 rows of dissepiments are present. Although differing in size and convexity, the dissepiments are apparently invariably steeply inclined. Lonsdaleoid dissepiments have not been observed in any of the specimens studied.

Tabulae are also sporadic at first, suggesting that their function of support was shared with the flanges. However, during subsequent stages they are invariably present and are commonly strongly depressed at the axis.

Internal lamellar stereozones may occur periodically and are especially characteristic of large specimens.

REMARKS: The specimen from the Eifelian of the Urals, identified by Soshkina and Dobrolyubova as *Lyriellasma subcaespitosum*, is here tentatively excluded from the species. It just falls within the range of the species in terms of degree of carination and abundance of septa, but the relative width of the tabularium is greater and the sclerenchymal investment general, rather than confined to definite layers.

***Lyriellasma chapmani* praecursor Philip 1962**

1962 *Lyriellasma subcaespitosum praecursor* Philip, p. 189, 190, Fig. 7a, b; Pl. 28, fig. 11, 12.

REMARKS: This subspecies was created for specimens of *Lyriellasma subcaespitosum* from Tyers R., which differed from topotypes in details of size, internal and peripheral stereozones, carination, lengths of counter and minor septa and in the incidence of lonsdaleoid dissepiments. Comparison of additional specimens (UNE F8879, F8880) from Tyers R. with the abundant material now available from Lilydale, leads to the rejection of some of the criteria originally cited as distinguishing the subspecies. Nevertheless, recognition of the subspecies is continued on the basis of the occurrence of interior stereozones, and the absence of lonsdaleoid dissepiments in the nominate subspecies.

***Lyriellasma* sp. nov., cf. *L. chapmani* nom. nov.**

(Pl. 2, fig. 10, 12; Fig. 2c)

MATERIAL: UNE F8933, a solitary corallite, incomplete proximally as well as distally, collected by G. M. Philip and the writer in the Coopers Creek Formation (late Gedinian or Siegenian) at Evans Brothers' Quarry near Coopers Creek, Vict. The site of this quarry is shown by Thomas (1942, p. 358); however the quarry does not expose Jordan River Beds as the reversed symbols suggest.

DESCRIPTION: Prior to sectioning, the length was 22 mm and the diameter at the lower end 8 mm; at the upper end, where the corallite was elliptical in cross section, the mean diameter was 10 mm. In addition to a peripheral lamellar stereozone varying in width from 0.3 to 1.0 mm, interior stereozones periodically invest the dissepimentarium and tabularium.

Septa  $24 \times 2$  in number, wavy and slightly pinnate in arrangement about an elongated cardinal, or counter septum; other major septa extend between two-thirds and the entire distance to the axis, while the minor are a little over one-half as long. When viewed in longitudinal section the trabeculae are inclined at between  $0^\circ$  and  $25^\circ$  to the horizontal.

7 to 10 rows of rather elongate and steeply inclined dissepiments are present.

The tabularium is slightly less than one-third of the width of the corallite, and perhaps to some extent due to subsequent distortion, slopes in one direction in the lower part of the longitudinal section. Higher in the corallite, tabulae are more normal for the genus, being somewhat axially depressed.

REMARKS: The specimen differs from known specimens of *Lyriellasma chapmani* of comparable size, in having a wider dissepimentarium composed of more numerous dissepiments. It is probably a new species, but obviously more material is required; before a definite stand can be taken on its taxonomic position.

Murray (1887, p. 45) noted that McCoy had identified 'traces of a lamelliferous coral closely allied to *Diplophyllum caespitosum*' in limestones, then regarded as Silurian, at Coopers Creek. Although these specimens are presumably lost, it is an interesting speculation that they may have been representatives of the same species.

True *Diplophyllum caespitosum* is an American Middle Silurian species and has recently been redescribed by Oliver (1963, p. 3).

### Genus *Embolophyllum* nov.

NAME DERIVATION: Gk,  $\epsilon\mu\beta\omicron\lambda\omicron\varsigma$  = wedge, and  $\phi\mu\lambda\lambda\omicron\nu$  = leaf.

TYPE SPECIES: *Acanthophyllum asper* Hill, redescribed below.

DIAGNOSIS: Corallum fasciculate, commonly dendroid but also phaceloid; corallites at first ceratoid to trochoid, later subcylindrical. Increase by both lateral and peripheral budding. Calice deep, steep sided. Wall thin to moderately thick, not reinforced by lamellar sclerenchymc. Septa radial to weakly pinnate in arrangement, typically expanded at the base so as to appear wedge shaped in transverse section; rarely withdrawn from the periphery. Carinae strongly to moderately developed in the tabularium. Trabeculae essentially parallel in longitudinal section, directed inwards, initially at  $10^\circ$  to  $30^\circ$  to the horizontal, but steepening towards the axis, to a possible maximum of  $45^\circ$ . Dissepiments numerous, predominantly vesicular rather than elongate. Tabulae incomplete, closely spaced and characteristically inclined towards the axis.

REMARKS: In growth form and other features the new genus resembles *Lyriellasma*, *Grypophyllum* and *Battersbyia* (= ? *Fasciphyllum*), all of which are discussed earlier in the paper. From the first it is distinguished by the absence of lamellar sclerenchymc, and from the others by the presence of pronounced carinae in the tabularium; *Battersbyia* and *Fasciphyllum* are further distinguished by the poverty of their dissepimentarium. *Acanthophyllum* Dybowski (1873, p. 339), in which the type species of *Embolophyllum* originally resided, is a solitary genus of corals, and as Bulvanker (1958, p. 95) and Birnheide (1961, p. 84) have independently pointed out, possesses a peripheral platform.

Although Wedekind's (1922, p. 8, 16) genus *Neostriophyllum* has been assigned to various families and has frequently accommodated disphyllinids (Soshkina 1952, Soshkina and Dobrolyubova in Orlov 1962, Bulvanker 1958, Spasskiy 1960, Besprozvannykh 1964), we must agree with Hill (in Moore 1956), Birnheide (1961) and others, that it is close to *Grypophyllum* and *ipso facto*, to *Embolophyllum*. Variation is wide, even among the spongophyllids referred to *Neostriophyllum*, and criteria cited in distinguishing one species group from *Embolophyllum* would not be the same as those used to distinguish another group. However, the new genus differs from all species of *Neostriophyllum* in being fasciculate.

Apart from the species described in this paper, the only other that seems certain to belong to *Embolophyllum* is *Cyathophyllum schucherti* Swartz (1913, p. 203, Pl. 20, fig. 5, 8, 9) from the Keyser Limestone of Maryland. The problems concerning the age of the Keyser are well known (Berdan 1964), but on the basis of Boucot's (1957, p. 1702; 1960, p. 291) correlations, *Embolophyllum schucherti* is probably an early Gedinnian species. This being so, the established range of the genus is Gedinnian to early (?) Emsian. *Neostriophyllum* on the other hand, is essentially a late Eifelian and Givetian genus, and even if corals such as *Cyathophyllum torquatum*, *sensu* Le Maître (1934, Pl. 5, fig. 16, 17) and *C. torquatum* var. *orientale* Reed (1922, Pl. 1, fig. 1-3) were included in it, the generic range, which would then be late Emsian to Frasnian (?), would still not overlap that of *Embolophyllum*.

Questions concerning the generic position of *Cyathophyllum mansfieldense* Dun cannot properly be answered until the type specimen is located and re-examined. The common variety at Loyola is a fasciculate coral and in several ways resembles



*Embolophyllum*. Apart from the probability of the type being a solitary coral, reluctance to ascribe the species definitely to *Embolophyllum* derives from the structure of the septa at the periphery. In places a normal septal stereozone is developed, but elsewhere trabeculae are bunched between the septa. Such an arrangement is often seen in other corals with naotic tendencies, particularly in Wedekind's (1923, p. 29, 35, Fig. 7; 1924, p. 76, Fig. 106-108) genus *Dohmophyllum* (Birenheide 1963, Fig. 3). Like *Cyathophyllum mansfieldense*, species of *Dohmophyllum* (= *Astrodiscus* Ludwig 1866, p. 212, Pl. 58; *Trematophyllum* Wedekind 1924, p. 72, 75, Fig. 104, 105; *Pseudoptenophyllum* Wedekind 1925, p. 60, 78, Pl. 16, fig. 95, 96) may be solitary or weakly compound (Frech 1885, Pl. 4, fig. 1-4) but have a wide peripheral platform and a patelloid corallum, at least in early stages. They are also of a different age, for with the exception of one recorded Upper Devonian occurrence (Unsalaner 1951, Pl. 1, fig. 2), *Dohmophyllum* is an Emsian (rare) and Middle Devonian genus, whereas *Cyathophyllum mansfieldense* is either Gedinian or Siegenian.

### ***Embolophyllum asper* (Hill 1940)**

(Pl. 2, fig. 11, 13-15; Pl. 3, fig. 6, 9; Pl. 4, fig. 1, 6; Fig. 5a-6)

1940b *Acanthophyllum asper* Hill, p. 252, Pl. 9, fig. 3a, b, ? 4.

**MATERIAL:** The type series consists of the holotype, UQ F4270, and one other figured specimen, UQ F4272; both were collected by Dorothy Hill from the 'Lower Middle Devonian' at the 'first karst on Cave Flat road from Wee Jasper, N.S.W.'

9 hypotypes from the same general area have been studied in connection with the present work. UNE F8911-F8917 were collected 50 to 60 ft above the base of the Taemas Limestone in a measured section on Goodradigbee R., approximately 8.5 kilometres N of Wee Jasper, N.S.W., grid reference 663714. UNE F8918 was gathered loose, about 60 ft above the base of the same limestone in another section near Goodradigbee R., approximately 6.6 kilometres N of Wee Jasper, grid reference 668695. UNE F8919 was collected 15 ft above the base of the Taemas Limestone in the section that also provided hypotypes F8911-F8917. In each instance the collectors were J. H. Jackson and the writer, and the age of the beds late Siegenian, or Emsian.

**DIAGNOSIS:** Corallum fasciculate, increase peripheral and lateral; mean diameter of adult corallites 16 to 23 mm. Calice steep sided. Wall thin, at septal bases typically wedge shaped in transverse section. Septa weakly bilateral in arrangement, normally thin and smooth near the periphery, or even withdrawn, becoming thicker and carinate in the tabularium. Septal counts  $25 \times 2$  to  $30 \times 2$  at maturity. Dissepiments globose to elongate, up to about 10 deep. Tabularium normal for family.

**DESCRIPTION:** Corallum fasciculate, generally dendroid rather than phaceloid; individual corallites at first are trochoid to ceratoid, but later become subcylindrical; the largest have a mean diameter of 16 to 23 mm. Rejuvenescence and both lateral and peripheral budding are not infrequent; a particularly good example of peripheral budding, involving 13 or more offsets, is seen in one corallite of the specimen catalogued as UNE F8913 (Fig. 5a). All available specimens are embedded in matrix, but it is clear from the arrangement of the dissepiments that the sides of the calice would be steep.

In transverse section the wall usually appears as a series of side-by-side wedges, which are due partly to expanded septal bases and partly to epithecal investment of these bases; in some specimens the wedge appearance is faint and may be entirely

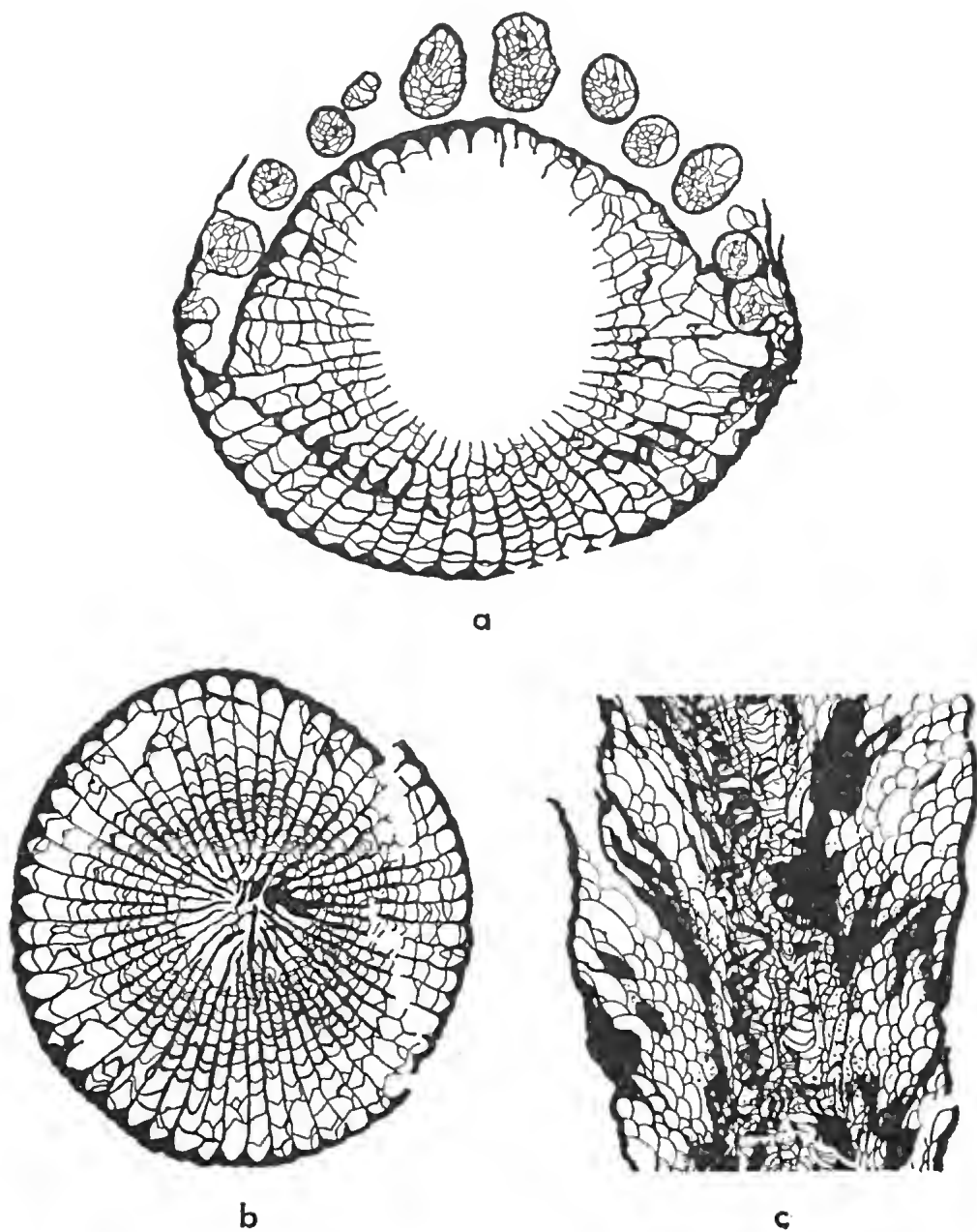


FIG. 5—*Embolophyllum asper* (Hill),  $\times 3$ . (a, b) UNE F8913, hypotype, transverse sections; (c) UNE F8911, hypotype, longitudinal section. Both specimens were collected 50 to 60 ft above the base of the Taemas Limestone near Wee Jasper, N.S.W.

absent. Shallow septal grooves and low interseptal ridges are sporadically developed. In its thinnest places the wall is normally between 0.1 and 0.3 mm thick, but may be as much as 0.5 mm.

The septal arrangement is weakly pinnate about an elongated septum believed to be the cardinal septum. Near the periphery septa are generally thin and smooth, but towards the axis commonly thicken and bear carinae. Major septa terminate near the supposed cardinal septum and are of unequal length; minor septa only

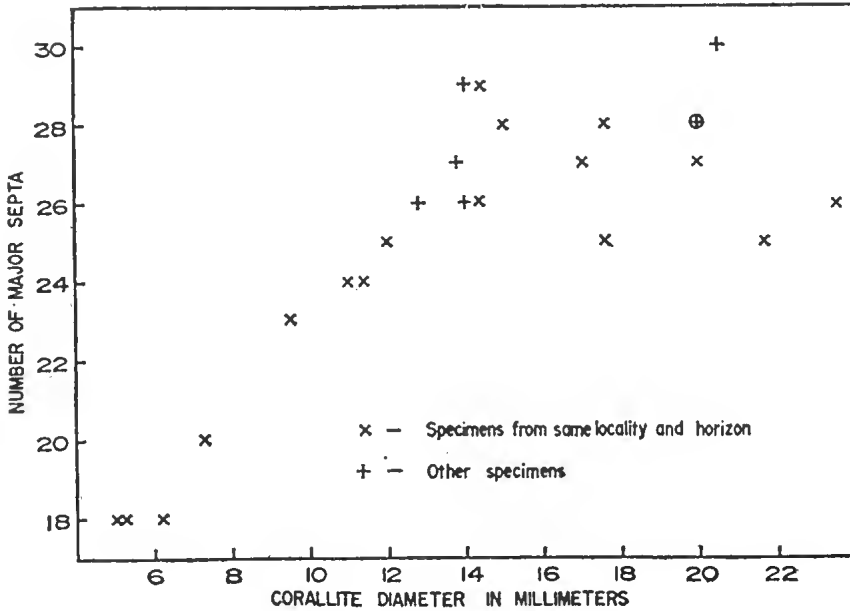


FIG. 6—*Embolophyllum asper* (Hill). Scatter diagram of number of major septa  $\times$  diameter in 10 specimens from four localities in the Taemas Limestone near Wee Jasper, N.S.W. Grid reference of the 'same locality' referred to is 663714. A point derived from the holotype is encircled.

just enter the tabularium. Septa of both orders may be withdrawn peripherally, especially during the early and late stages of a corallite's development. Septal counts are expressed as a scatter diagram in Fig. 6.

Dissepiments are globose to elongate and decrease only slightly in inclination towards the periphery; they are approximately 6 deep in corallites of about 10 mm diameter and 8 to 10 deep in fully grown specimens.

The tabularium is one-third to two-fifths of the total width of the corallite and consists of closely spaced and incomplete tabulae; an axial sag may or may not be present.

REMARKS: Although the type specimen was described as solitary, all specimens subsequently collected from the type area are colonial, and there is in fact, on one side of the holotype, a small corallite suggesting that this specimen is also part of a fasciculate colony.

**Embolophyllum aggregatum (Hill)**

It was not evident at first that *Embolophyllum aggregatum* and *E. asper* are especially closely related; indeed they were ascribed to different families. However subsequently, specimens have been collected which are both stratigraphically and morphologically intermediate, and it is now highly probable that *E. aggregatum* descended directly from *E. asper*. This phylogeny involved firstly a diminution of corallite diameter accompanied by a change from dendroid to phaceloid corallum, and secondly a dilation of the septa with consequent development of a peripheral stereozone.

The second is perhaps a comparatively minor step, but is nevertheless expressed taxonomically by the erection of a new subspecies for the forms preceeding it.

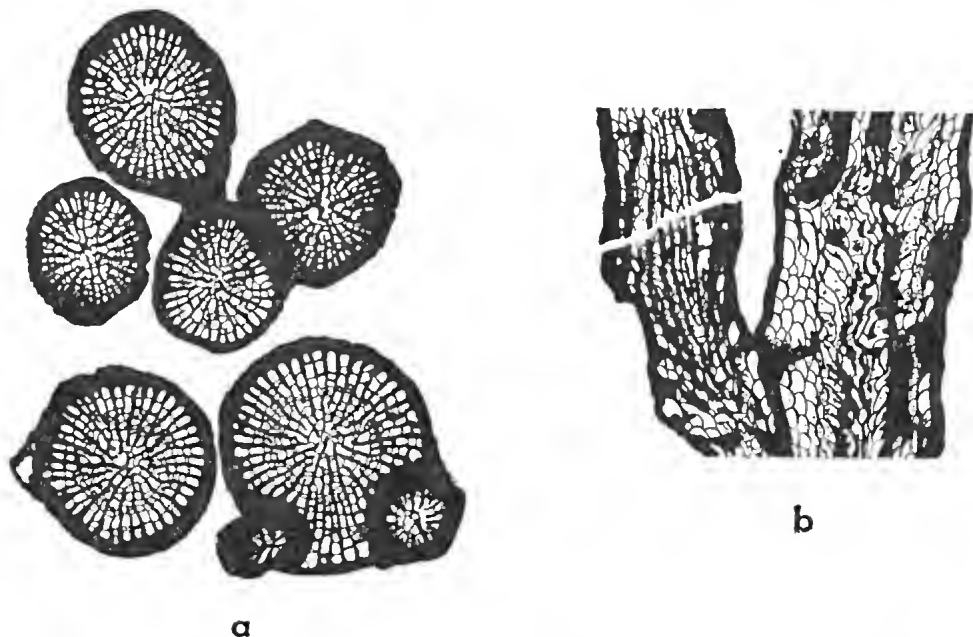


FIG. 7—*Embolophyllum aggregatum aggregatum* (Hill),  $\times 3$ . (a) UNE F8885, hypotype, transverse section; (b) same specimen, longitudinal section. 588 to 638 ft above the base of the Taemas Limestone, near Wee Jasper, N.S.W.

***Embolophyllum aggregatum aggregatum* (Hill 1940)**

(Pl. 3, fig. 3; Pl. 4, fig. 3-5, 7-9; Fig. 7a-8)

1940b *Grypophyllum aggregatum* Hill, p. 263, 269, Pl. 10, fig. 8; Pl. 11, fig. 1.

? 1942c ? *Grypophyllum* ? *aggregatum* Hill, Hill, p. 183, Pl. 6, fig. 4.

**MATERIAL:** The holotype, AM F10132, was presented to the museum in 1904 by Miss Yeo and is stated (Hill 1940b) to be from the 'Lower Middle Devonian Cave Limestone, Wee Jasper, Goodradigbee R.'; the current view is that it was probably obtained from an Emsian horizon within the Taemas Limestone. A paratype, UQ F4314, is simply located (Hill 1940b, legend Pl. 10) 'Wee Jasper'.

A further 19 specimens have been collected by J. H. Jackson and the writer from the type area. Of these, UNE F8885-F8897 occurred between 588 and 638 ft

above the base of the Taemas Limestone in a measured section, approximately 3 kilometres N of Wee Jasper, N.S.W., grid reference 677658, and UNE F8898-F8903 between 523 and 528 ft above the base of the same limestone in another section, approximately 8.5 kilometres N of Wee Jasper, grid reference 661711.

**DIAGNOSIS:** Corallum phaeoloid, increase peripheral and lateral; adult corallite diameter 6.0 to 11.5 mm. Calice steep sided. Septa earinate and dilated, especially at the periphery where there is a stereozone up to 0.5 mm thick; septal counts in adult corallites  $18 \times 2$  to  $23 \times 2$ . Dissepiments steeply inclined, normally 2 to 5 deep. Tabularium strongly depressed medianly.

**DESCRIPTION:** The corallum is large, fasciculate and commonly phaeoloid. Individual corallites are subcylindrical, but in places may be flattened by contact with neighbouring corallites; their mean diameter when fully grown is normally 6.0 to 9.5 mm and exceptionally as much as 11.5 mm. Evidence of rejuvenescence has not been observed; however both lateral and peripheral budding can be seen in the hypotypes studied. Inclination of the dissepiments and slope of the tabulae indicate a deep calice with steep sides. There are no indications of septal grooves or interseptal ridges.

The peripheral wall is typically 0.3 to 0.5 mm thick, but whether this is entirely or just partly a septal stereozone is not clear, due to poor preservation. Septal arrangement is either radial or weakly pinnate. Major septa are unequal in length, the longest penetrate the axial region, while the shortest extend less than one-quarter

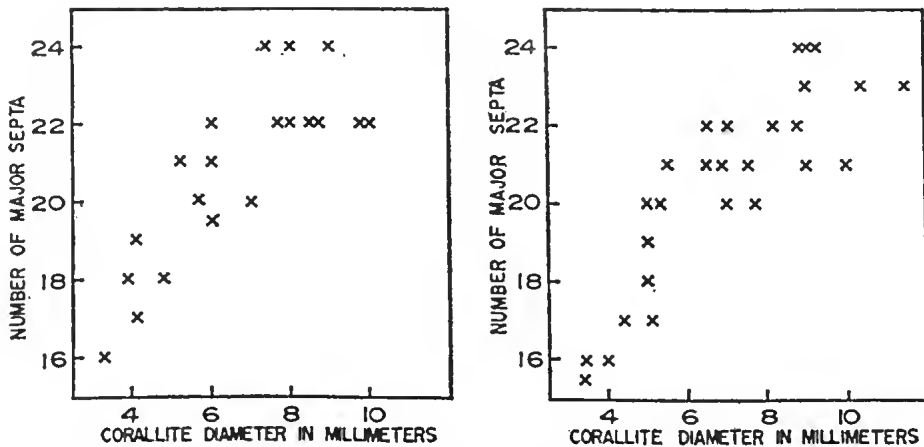


FIG. 8—*Embolophyllum aggregatum aggregatum* (Hill). Scatter diagrams of number of major septa  $\times$  diameter. Left hand diagram based on 13 specimens collected between 588 and 638 ft above the base of the Taemas Limestone at a locality (grid reference 677658) near Wee Jasper, N.S.W. Right hand diagram based on 6 specimens collected from 523 to 528 ft above the base of the same limestone at another locality (grid reference 661711) near Wee Jasper.

of the distance across the tabularium; peripheral withdrawal is unknown. Both orders are carinate and dilated; towards the periphery dilation may be especially prominent. Numerical details of the septa are given in the scatter diagrams of Fig. 8.

Although variable, dissepiments are, on the whole, relatively large, elongate, and steeply inclined even at the periphery. Normally they are in 2 to 5 rows and in places may be thinly invested by sclerenchyme.

The tabularium, which is about two-fifths of the total width of the corallite is constituted predominantly of somewhat inflated, inwardly sloping and incomplete tabulae.

***Embolophyllum aggregatum cracente* subsp. nov.**

(Pl. 3, fig. 1, 2, 4, 5, 7, 8; Pl. 4, fig. 2; Fig. 9a-10)

NAME DERIVATION: *L. cracens* = graceful.

TYPE SERIES: Holotype and paratypes 1-6, UNE F8904-F8910 respectively, collected by J. H. Jackson and the writer 443 to 448 ft above the base of the Taemas Limestone (early Emsian part), in a measured section on Goodradigbee R. approximately 8.5 kilometres N of Wee Jasper, N.S.W., grid reference 661711.

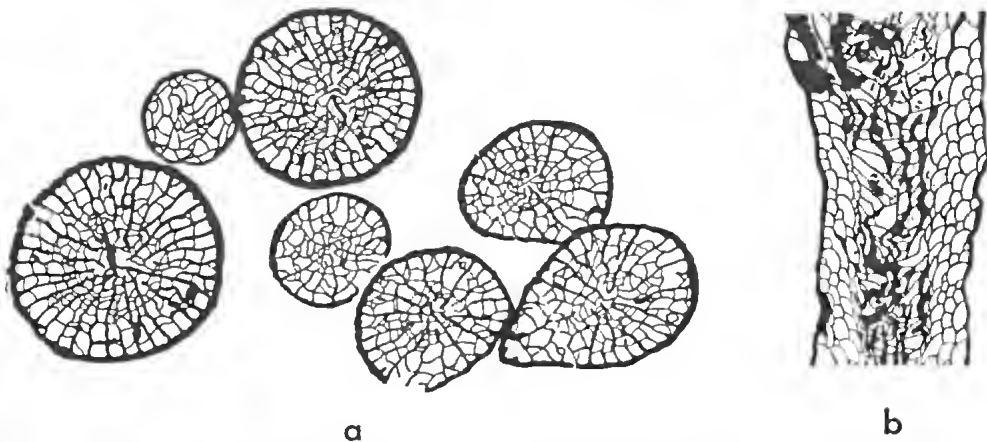


FIG. 9—*Embolophyllum aggregatum cracente* subsp. nov.,  $\times 3$ . (a) UNE F8906, paratype 2, transverse section; (b) UNE F8907, paratype 3, longitudinal section. Both specimens were collected between 443 and 448 ft above the base of the Taemas Limestone near Wee Jasper, N.S.W.

DIAGNOSIS: Corallum phaceloid, locally subecrioid, increase peripheral and lateral; adult corallite diameter 7.5 to 14.5 mm, normally 8.0 to 11.0 mm. Calice with steep sides. Septa carinate, thin, except for some peripheral dilation; septal counts  $17 \times 2$  to  $21 \times 2$  in fully grown corallites; minor septa may be withdrawn from periphery. Dissepiments steeply inclined, 2 to 4 rows in average corallites. Tabularium typical of family.

DESCRIPTION: Corallum large, phaceloid; individual corallites circular to elliptical in cross section; commonly they are sufficiently crowded for the corallum to be locally subecrioid. Rejuvenescence, lateral budding and peripheral budding are all seen in the type series. Adult corallites vary from about 7.5 to 11.0 mm in diameter, but in exceptional cases may exceed 14.0 mm. Longitudinal sections indicate that the calice is deep with steep sides.

The wall is normally 0.1 to 0.3 mm thick, but reaches a maximum of 0.5 mm. Septa radial to weakly pinnate in arrangement, carinate and thin, except for variable dilation at the periphery; in extremely rare instances there is a suggestion of a peripheral stereozone. Major septa vary to the extent that the shortest project only slightly into the tabularium while the longest extend to the axis or beyond. Minor septa are equally variable: some are almost completely suppressed, while others

enter the tabularium. In young corallites both orders of septa are discontinuous or withdrawn; later, peripheral withdrawal of the minor septa may persist locally, but the major are almost invariably complete. Numbers of septa at given diameters are shown by scatter diagram in Fig. 10. An average dissepimentarium consists of about 2 to 4 rows of moderately sized and steeply inclined dissepiments; in large corallites with a diameter of the order of 14 mm, there are as many as 8 or 9 rows.

Tabulae are incomplete, closely spaced and those at the margin are invariably inwardly inclined. Breadth of tabularium is one-third to two-fifths of the width of the entire corallite.

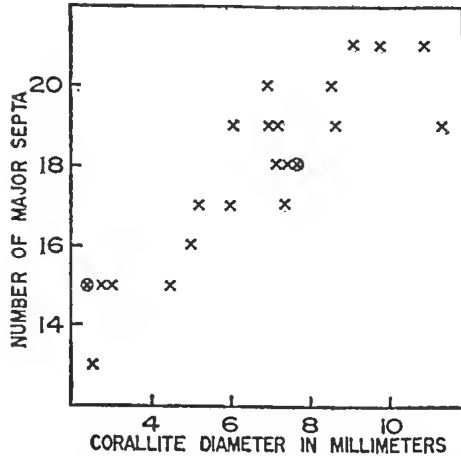


FIG. 10—*Embolophyllum aggregatum cracente* subsp. nov. Scatter diagram of number of major septa  $\times$  diameter in the 7 specimens constituting the type series. Points derived from the holotype are encircled.

REMARKS: The new subspecies differs from the nominate subspecies in having larger, generally more closely spaced corallites, and more numerous and less dilated septa. Compared with *E. asper* it is phaeclloid to subeerioid rather than dendroid, the individual corallites are smaller and the number of septa less.

#### ***Embolophyllum aequiseptatum* (Hill)**

This species was first recognized in the Cavan Bluff Limestone on Clear Hill overlooking Murrumbidgee R. in the Taemas-Cavan area of N.S.W.; subsequently it has been identified in the Garra Beds and Nubrigyn Limestone of the Molong-Wellington area, N.S.W., and in limestones at Buchan and on Tyers R. in Viet.

D. L. Strusz has acquired further specimens from the Garra Beds and regards them as representing a new species. The single specimen from Tyers R. has unusually thick septa with correspondingly thin interseptal loculi and is probably a new species. Minor differences between specimens from the Buchan Caves and Cavan Limestones suggest that they should be referred to distinct subspecies. The Nubrigyn specimens (K. H. Wolf in Johnson 1964, p. 98) have not been described, nor have they been seen by the writer.

#### ***Embolophyllum aequiseptatum aequiseptatum* (Hill 1940)**

(Pl. 5, fig. 2, 4, 6, 7; Pl. 6, fig. 3, 4, 6; Fig. 11a-12)

1940b *Acanthophyllum aequiseptatum* Hill, p. 251, Pl. 9, fig. 1, 2.

1959 *Acanthophyllum aequiseptatum* Hill, Browne, p. 118.

non 1942c *Acanthophyllum aequiseptatum* Hill, Hill, p. 183, Pl. 6, fig. 1 (= n.sp.).

non 1950 *Acanthophyllum aequiseptatum* Hill, Hill, p. 139, Pl. 5, fig. 1 (= subsp. *buchanense*).

non 1962 *Acanthophyllum aequiseptatum* Hill, Philip. p. 184, 185, Pl. 26, fig. 2, 3 (= n.sp.).

**MATERIAL:** Holotype, AM F9577, collected by A. J. Shearsby at Clear Hill, Parish of Cavan, N.S.W. Paratype, AM F17102, collected by W. S. Dun at Cavan N.S.W. It is believed that both of these came from the Cavan Limestone of late Siegenian or Emsian age.

5 hypotypes are from collections made by J. H. Jackson and the writer in the Cavan Limestone of the Wee Jasper area, N.S.W. UNE F8920, F8921 are from the W bank of Goodradigbee R., 6 kilometres N of Wee Jasper, grid reference 673688, while UNE F8922, F8935, F8936 are from the N end of Barbers' Island, about 11 kilometres N of Wee Jasper, grid reference 657736.

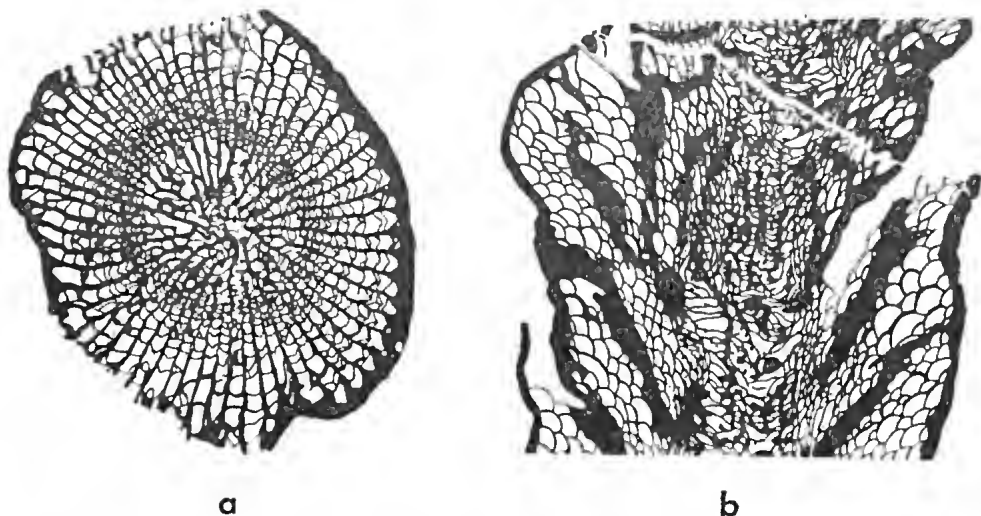


FIG. 11—*Embolophyllum aequiseptatum aequiseptatum* (Hill),  $\times 3$ . (a) UNE F8920, hypotype, transverse section; (b) same specimen, longitudinal section. Cavan Limestone, Goodradigbee R., near Wee Jasper, N.S.W.

**DIAGNOSIS:** Dendroid corallum, increase both peripheral and lateral; mature corallites 16 to 23 mm in diameter. Calice deep, bell shaped. Septal bases expanded, wedge shaped in transverse section. Septa strongly flanged in tabularium and numbering  $25 \times 2$  to  $31 \times 2$  in adult corallites. Dissepiments numerous, steeply inclined at the periphery becoming even steeper towards the centre. Tabularium one-quarter to one-third as wide as the corallite; tabulae closely spaced, incomplete and in general, sloping towards the axis.

**DESCRIPTION:** Colony weakly dendroid, consisting of corallites, which are at first ceratoid to trochoid, and later subcylindrical with a mean diameter of 16 to 23 mm. Rejuvenescence frequent. Peripheral and lateral increase are demonstrable in hypotype UNE F8920; before sectioning it could be seen that the small corallites in fig. 4 of Pl. 5 are peripheral offsets from the larger corallite (now filled with a stromatoporoid); it could also be seen that the small corallite in fig. 7 of Pl. 5 is a lateral bud from the upper corallite of the same figure. Although not exposed in the present material, the calice is evidently deep and has the shape of an inverted bell.



The wall is probably fibrous inside the axial plate and in transverse section usually appears as a row of contiguous wedges; less commonly the septal bases, which are partly responsible for the wedges, are sufficiently expanded to form a narrow stereozone approximately 0.2 to 0.5 mm thick. Where the individual wedges join, the wall is about 0.2 to 0.5 mm thick; other parts, of course, are thicker. Septa radial, or just bilateral in arrangement and, apart from their peripheral expansion, are not especially dilated. Carinae are extremely fine and sporadic in the dissepimentarium, however in the tabularium the septa are strongly flanged and appear rhopaloid in transverse section. Major septa are unequal in length: some extend beyond the axis, others terminate 2 or 3 mm short of it. In contrast, the minor septa terminate uniformly near the inner margin of the dissepimentarium. The number of septa at given mean diameters is shown in Fig. 12. Although wavy when viewed in longitudinal section, the trabeculae are essentially parallel and directed inwards at angles of  $10^{\circ}$  to  $45^{\circ}$  to the horizontal.

The dissepimentarium is well developed, there being about 8 to 13 rows of dissepiments in adult corallites. Dissepiments are of moderate size and inclination throughout most of the dissepimentarium; however in the vicinity of the tabularium they are generally smaller and more steeply inclined.

Width of tabularium is one-quarter to one-third that of the corallite, except following a rejuvenescence when it is relatively greater. Tabulae are incomplete and normally slope towards the axis; as in other members of the family the marginal tabulae may be somewhat inflated.

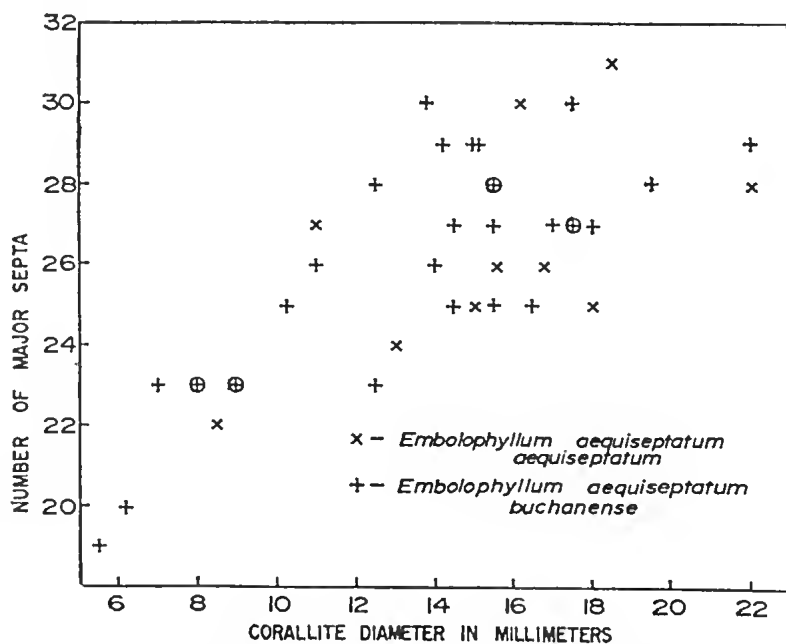


FIG. 12—*Embolophyllum aequiseptatum* (Hill). Scatter diagram of number major septa  $\times$  diameter in 5 specimens of subspecies *aequiseptatum* from two localities near Wee Jasper, N.S.W. and 7 specimens of subspecies *buchanense* from a single locality (97 of Teichert and Talent 1958) near Buchan, Vict. Points derived from holotypes are encircled.

***Embolophyllum aequiseptatum buchanense* subsp. nov.**

(Pl. 5, fig. 1, 3, 5; Pl. 6, fig. 1, 2, 5, 7; Fig. 12-13b)

1950 *Acanthophyllum aequiseptatum* Hill, Hill, p. 139, Pl. 5, fig. 1.1950 *Acanthophyllum* sp., Hill, p. 139, Pl. 5, fig. 2.

NAME DERIVATION: Town of Buchan, Vict.

MATERIAL: The holotype, UNE F8923, and paratypes 1-6, UNE F8924-F8929 respectively, were collected by G. M. Philip and the writer from the Buchan Caves Limestone (late Siegenian or Emsian) on the road from Buchan to Orbost, Vict. (locality 96-98 of Teichert and Talent 1958).

The specimen, GSV 47765, figured by Hill as *Acanthophyllum aequiseptatum* is an exact topotype; others, GSV 47713, 47714, figured as *Acanthophyllum* sp., are from the same general area; all three were collected by Curt Teichert.

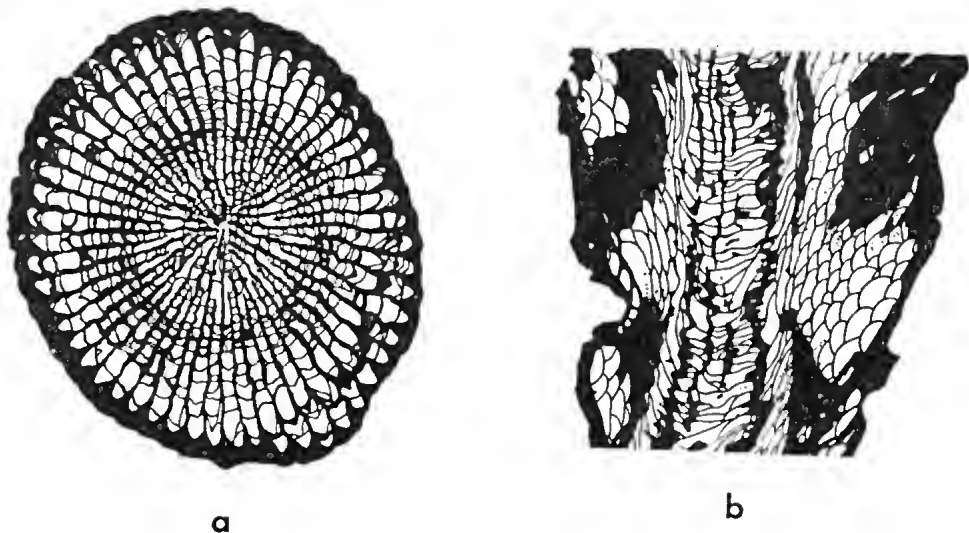


FIG. 13—*Embolophyllum aequiseptatum buchanense* subsp. nov.,  $\times 3$ . (a) UNE F8928, paratype 5, transverse section; (b) UNE F8925, paratype 2, longitudinal section. Both specimens are from the Buchan Caves Limestone at locality 97 of Teichert and Talent (1958) near Buchan, Vict.

DIAGNOSIS: Corallum dendroid to phacclloid; lateral budding known, peripheral budding suspected, but not proven. Adult corallites 13 to 22 mm in diameter. Calice deep, bell shaped. Septa prominently flanged in the tabularium and commonly strongly dilated at the periphery, forming a stercozone approximately 1 mm thick. Septal counts  $25 \times 2$  to  $30 \times 2$  per adult corallite. Septal grooves and interseptal ridges common, locally strongly developed. Dissepiments numerous, steeply inclined. Tabularium one-third to three-eighths of the total width of the corallite; tabulae closely spaced and inclined towards the centre.

REMARKS: The new subspecies is so similar to the nominate subspecies, fully described above, that a full description is not warranted. Compared with *E. aequiseptatum*, *sensu stricto*, the corallum is larger, more clearly colonial, and commonly phaceloid rather than dendroid; the average thickness of the wall is

greater and because it is locally deeply invaginated, may seem quite confluent with the septa; septal grooves and interseptal ridges, which may be entirely absent in the nominate subspecies, are more strongly developed; the innermost dissepiments tend to be coarser, there are however, exceptions to this; the width of the tabularium is between one-third and three-eighths of the total width of the corallite, whereas in *aquiseptatum*, *sensu stricto*, it is between one-quarter and one-third of the width of the corallite.

***Embolophyllum mundum* sp. nov.**

(Pl. 7, fig. 1, 3)

1950 *Lyriasma* aff. *floriforme* Hill, Hill (*partim*), p. 140, Pl. 5, fig. 4.  
non 1942b *Lyriasma floriforme* Hill, p. 146, 147, Pl. 2, fig. 2.

NAME DERIVATION: *L. mundus* = neat.

MATERIAL: The holotype, UNE F8934, was collected by G. M. Philip and the writer in the Taravale Mudstone (Emsian) at the entrance to the Buchan Caves Reserve, Vict. A paratype, GSV 48129, was collected by Curt Teichert in 'lower Murrindal beds', one-half mile north of Buchan R. Bridge (locality 167 of Teichert and Talent 1958). This is the specimen figured by Hill and in terms of current nomenclature also came from the Taravale Mudstone.

The other coral, GSV 48460, identified by Hill as *Lyriasma* aff. *floriforme*, is excluded from the new species; it was also collected by Teichert, but apparently from beds which would now form part of the Murrindal Limestone.

DIAGNOSIS: Corallum fasciculate, increase where observed peripheral; individual corallites ceratoid to subcylindrical with maximum diameter 16 mm. Sides of calice steep. Septa radially arranged, carinate, especially in the tabularium, and dilated at the periphery; cardinal septum long. Dissepiments variable, but generally inflated and about 5 or 6 deep. Tabularium with a marked axial depression.

DESCRIPTION: The paratype indicates that the corallum is fasciculate and demonstrates peripheral budding in the species; individual corallites are ceratoid to subcylindrical and have a maximum mean diameter of approximately 15 mm. The exterior is not exposed in the material at hand, but it may be assumed from sections that the calice is deeply funnel shaped.

Peripheral ends of the septa are expanded, so that in transverse section the wall resembles a series of wedges; thickness at the junction of these wedges is typically 0.5 to 0.7 mm. Although the cardinal and counter septa may be elongated, the arrangement of the septa is otherwise radial. Flanged carinae are particularly prominent in the tabularium, and the septa may also be slightly carinate in the dissepimentarium. Major septa variable in length: some only just penetrate the tabularium, whereas others extend to the axial region; minor septa are equally variable and typically about two-thirds to four-fifths as long as the major; normally they do not enter the tabularium. Septal counts with diameters expressed in mm are as follows:

Specimen	Status	Mean diameter	No. of Septa
GSV 48129	Paratype	6.0	18 × 2
GSV 48129	Paratype	12.0	22 × 2
GSV 48129	Paratype	14.0	28 × 2
UNE F8934	Holotype	15.5	29 × 2

Trabeculae are directed inwards at an angle of approximately 40° to the horizontal.

Dissepiments vary considerably in size and inclination; most however, are inflated and some are thickened by sclerenchymal investment; commonly 5 or 6 irregular rows are present.

The tabularium is one-third to three-fifths as wide as the corallite and consists of closely spaced incomplete tabulae. Typically these slope towards the axis and tend to be much broken up by the long flanged septa.

REMARKS: The author now has at his disposal a large number of specimens of *Lyriellasma floriforme* from the type area near Attunga, N.S.W. Compared with *Embolophyllum mundum*, these specimens have fewer septa (maximum  $26 \times 2$  versus  $29 \times 2$  in *E. mundum*), a much more pronounced peripheral stereozone (up to 3.5 mm thick), constituted partly of lamellar sclerenchyme, smoother septa, especially in the tabularium, and quite commonly a loose axial structure. The belief that the new species is geologically older than *L. floriforme*, further justifies the erection of a new species.

The corallite diameter and number of septa fall within the range of *Embolophyllum asper*; the two species are also of similar age. In *E. asper* however, the septa are finer, less carinate and locally withdrawn from the periphery.

### *Embolophyllum* (?) *mansfieldense* (Dun 1898)

(Pl. 7, fig. 2, 6; Fig. 14-15)

- 1898 *Cyathophyllum mansfieldense* Dun, p. 87, 88, Pl. 3, fig. 3, 4.  
 1939 *Acanthophyllum mansfieldense* (Dun), Hill, p. 223, 224, Pl. 15, fig. 1-3.  
 1962 *Acanthophyllum mansfieldense* (Dun), Philip, p. 186, Pl. 26, fig. 11, 12.  
 1962 *Acanthophyllum mansfieldense* (Dun) ?, Philip, Pl. 26, fig. 9, 10.  
 ? 1962 *Acanthophyllum sweeti* (Etheridge), Philip (*non* Etheridge), p. 187, Pl. 26, fig. 7, 8.  
 ? 1964 *Acanthophyllum mansfieldense* (Dun), Spasskiy in Dubatolov and Spasskiy, p. 72.  
 non 1940a *Acanthophyllum* sp. cf. *mansfieldense* (Dun), Hill, p. 152, Pl. 2, fig. 1.  
 non 1942b *Acanthophyllum* ? *mansfieldense* (Dun), Hill, p. 146, Pl. 2, fig. 1.  
 non 1942c *Acanthophyllum* cf. *mansfieldense* (Dun), Hill, p. 182, Pl. 5, fig. 1.

MATERIAL: The holotype was collected by George Sweet from the Loyola Limestone (late Gedinnian or Siegenian) at Griffith's Quarry near Mansfield, Vict.; it may well be in the National Museum of Victoria, where much of Sweet's collection is stored, but at the present time has not been located.

7 or 8 topotypes are known. Two of these, UM TS608-TS610, were obtained by E. A. Ripper, the remainder, UNE F8881-F8884, F8930, F8931, by the writer. Of these, F8881-F8884 and F8931 are referred to a new variety name *fecundum*.

There are about 10 specimens from limestones in the Coopers Creek Formation (late Gedinnian or Siegenian) on Tyers R., Vict. The best of these are MU TS1594, TS1595 (locality 20 of Philip 1962, p. 125), TS1596, TS1597, TS1608, TS1610 (locality 3 of Philip), TS1606, TS1607 (locality 15 of Philip, figured as *A. sweeti*) and UNE F8932 (locality 15 of Philip). The last was collected by G. M. Philip and the writer, and the others by Philip alone.

REMARKS: The material recently collected at Loyola is distinctly separable into two varieties, and rather surprisingly the rarer of these conforms more closely with the descriptions of the species given by Dun (1898) and Hill (1939).

In stages preceding the attainment of a corallite diameter of 16 to 20 mm or so, septa are added at a rate such that the ratio between the width of septa and inter-septal loculi is approximately constant. Subsequently the coral develops in one of two ways. In one, the corallite remains trochoid, and very few, if any, new septa are added while it enlarges to a maximum diameter of about 40 mm; the septa become dilated, usually periodically, and there may be local naotic tendencies. In

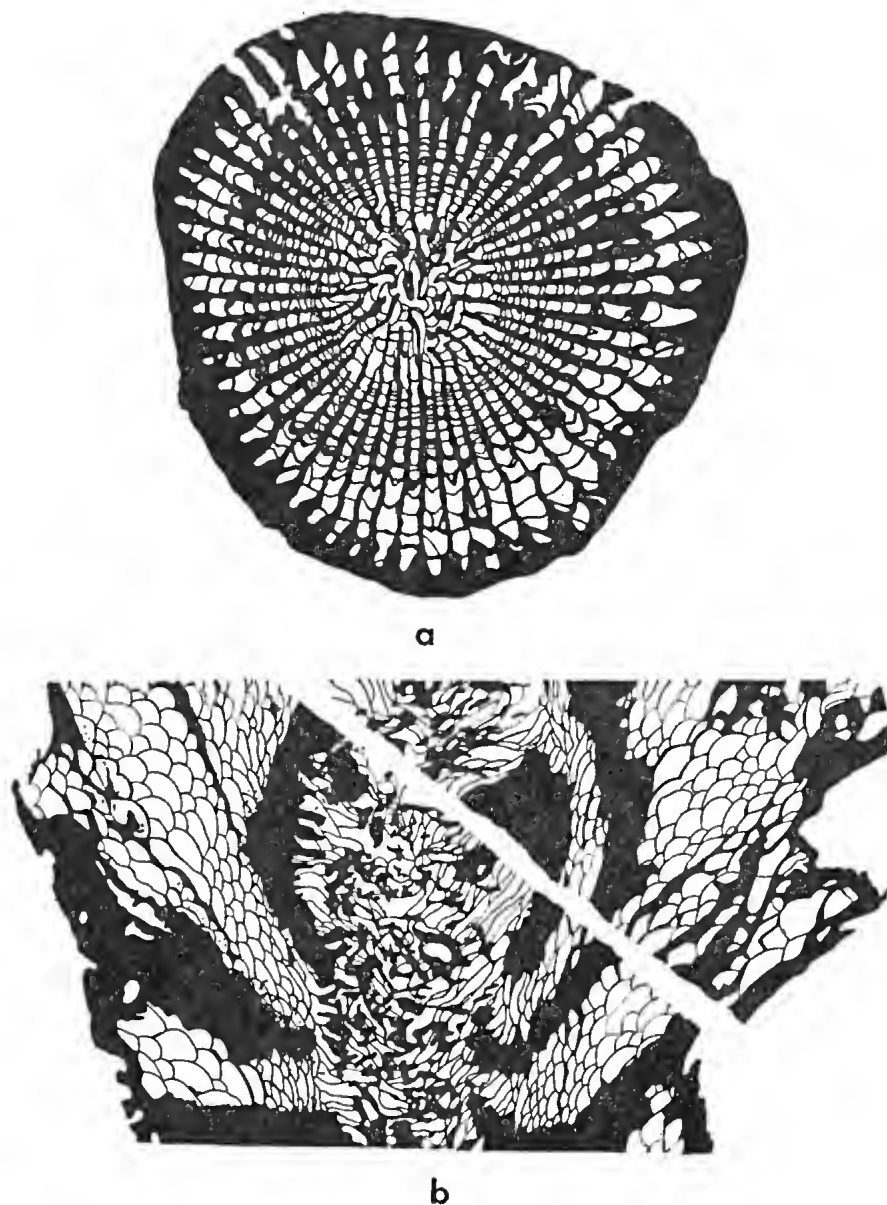


FIG. 14—*Embolophyllum* (?) *mansfieldense* (Dun),  $\times 3$ . (a) UNE F8930, hypotype, transverse section; (b) same specimen, longitudinal section. Loyola Limestone at Griffith's Quarry near Mansfield, Vict.

the other kind of development, addition of septa continues as before, the corallites become subcylindrical and lateral offsets lead to the development of a fasciculate corallum.

Wedge-wise dilation of the septa, which is apparent in Dun's figure of the holotype, is symptomatic of the first of the two types of development described above. Specimens of *E. (?) mansfieldense* exhibiting the second kind of development are referred below to a new variety named *fecundum*.

Hill (1940, 1942c) has compared a specimen from the Silverwood Series of S. Queensland and others from the Garra Beds of N.S.W. with this species. The presence of a peripheral platform and only 20 major septa at a diameter of 30 mm, excludes the Silverwood form from the species. The Garra specimens are presently under study by D. L. Strusz, who is tentatively placing them in a new species; the sole figure published to date is insufficient for identification.

Hill (1942b) has also doubtfully identified a specimen from the Tamworth Group with this species. In doing so she noted the strong septal dilation and the low number of septa in the Tamworth form. Now that the variation of *Embolophyllum (?) mansfieldense* is more fully understood, it is even less likely that the specimen is correctly identified with it.

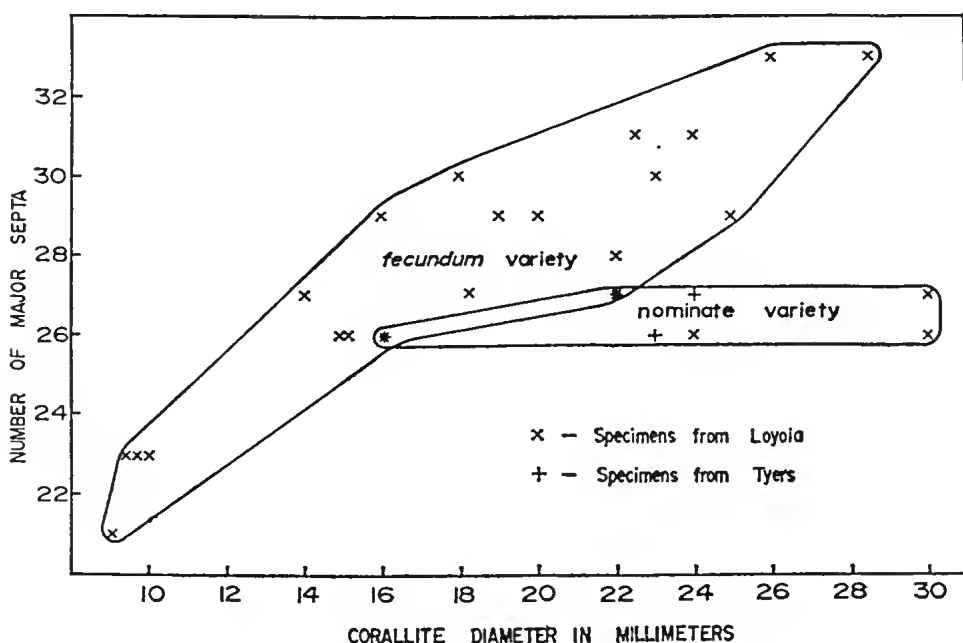


FIG. 15—*Embolophyllum (?) mansfieldense* (Dun). Scatter diagram of number of major septa  $\times$  diameter in 6 specimens from the Loyola Limestone at Griffith's Quarry near Mansfield, Vict. and 4 specimens from a limestone in the Coopers Creek Formation on Tyers R., Vict.

Spasskiy (in Dubatolov and Spasskiy 1964) lists the species from the Lower Devonian of the Omulevskic Mountains in NE. Siberia; however the writer is not aware that this occurrence has been substantiated by published description or figures.

The generic identity of *Cyathophyllum mansfieldense* is discussed fully under the remarks on *Embolophyllum*.

**Embolophyllum (?) mansfieldense var. fecundum nov.**

(Pl. 7, fig. 4, 5, 7)

NAME DERIVATION: *L. fecundus* = fertile.

DIAGNOSIS: Corallum fasciculate, commonly phaceloid; increase, where observed lateral; adult corallites 16.0 to 28.5 mm in mean diameter. Periphery essentially a septal stereozone. Calice deep, funnel shaped. Septa radial to weakly pinnate in arrangement, numbering  $27 \times 2$  to  $33 \times 2$  in mature corallites. Dissepiments typically elongate, 8 to 14 deep. Tabularium normal for genus, width one-quarter to one-third that of the entire corallite.

DESCRIPTION: Corallum large, more or less phaceloid; lateral offsets occur, but at the moment there is no evidence of peripheral increase. Initially corallites are trochoid to ceratoid, and subsequently subcylindrical, with a typical mean adult diameter of 16.0 to 26.0 mm and a maximum of 28.5 mm. Sections indicate that the calice would be deeply funnel shaped.

Septa are radially arranged in some corallites, and in others are weakly pinnate about the cardinal-counter plane; at the periphery they are strongly dilated and usually contiguous forming a stereozone from 0.5 to 2.0 mm wide. Major septa flanged and commonly rhopaloid; in radially symmetrical corallites they extend to the axial region, but in bilaterally symmetrical ones, those close to the plane of symmetry may terminate well short of the axis. Minor septa only just project into the tabularium. Septal counts appear as a scatter diagram in Fig. 15. Trabeculae subparallel; inclination variable, maximum  $45^\circ$ .

Dissepiments typically elongate, steeply inclined and about 8 to 14 deep in a fully developed dissepimentarium.

Tabulae are closely spaced, incomplete and inclined towards the axis. The interior of the tabularium is poorly preserved, but appears to be dominated by septal ends and flanges. Width of the tabularium is one-quarter to one-third of the diameter of the corallite.

REMARKS: The closest previously described species is *Fasciphyllum isfajramense* Pavlova (1963, p. 42, 43, Pl. 6) from the Gedinnian of southern Ferghana. By comparison the new variety generally has fewer septa at a given diameter and finer dissepiments.

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## Explanations of Plates

L.S. and T.S. are the abbreviations used throughout for longitudinal and transverse sections respectively

### PLATE 1

All figures  $\times 3$

- FIG. 1-14—*Lyriellasma chapmani chapmani* nom. nov. (1) UNE F8877, hypotype; (2) UNE F8872, hypotype; (3) NMV P23009, hypotype; (4) UNE F8869, hypotype; (5) UNE F8864, hypotype; (6) NMV P23018, hypotype; (7) UNE F8862, hypotype; (8) UNE F8865, hypotype; (9) NMV P15970, holotype; (10) UNE F8863, hypotype; (11) UNE F8868, hypotype; (12) UNE F8860, hypotype; (13) NMV P15971, holotype; (14) NMV P23016, hypotype. All T.S. and from the Lilydale Limestone at Cave Hill, Lilydale, Vict.

### PLATE 2

Fig. 1-10, 12  $\times 3$ ; Fig. 11, 13-15  $\times 2$

- FIG. 1-9—*Lyriellasma chapmani chapmani* nom. nov. (1) UNE F8872, hypotype, L.S.; (2) UNE F8877, hypotype, L.S.; (3) UNE F8870, hypotype, L.S.; (4) NMV P23009, hypotype, tangential section; (5) NMV P15972, holotype, L.S.; (6) UNE F8876, hypotype, L.S.; (7) NMV P15972, holotype, L.S.; (8) UNE F8871, hypotype, L.S.; (9) UNE F8860, hypotype, L.S. All from the Lilydale Limestone at Cave Hill, Lilydale, Vict.
- FIG. 10, 12—*Lyriellasma* sp. nov., cf. *L. chapmani* nom. nov. (10) UNE 8933, hypotype, T.S.; (12) UNE F8933, hypotype L.S. Coopers Creek Formation, Coopers Creek, Vict.
- FIG. 11, 13-15—*Embolophyllum asper* (Hill) gen. nov. (11) UNE F8911, hypotype; (13-15) UNE F8912, hypotype. All L.S. and from between 50 and 60 ft above the base of the Taemas Limestone, near Wee Jasper, N.S.W.

### PLATE 3

All figures  $\times 2$

- FIG. 1, 2, 4, 5, 7, 8—*Embolophyllum aggregatum cracente* gen. et subsp. nov. (1) UNE F8905, paratype 1, T.S.; (2) UNE F8904, holotype, T.S.; (4) UNE F8904, holotype, L.S.; (5) UNE F8906, paratype 2, L.S.; (7) UNE F8907, paratype 3, L.S.; (8) UNE F8905, paratype 1, L.S. All from 443 to 448 ft above the base of the Taemas Limestone, near Wee Jasper, N.S.W.
- FIG. 3—*Embolophyllum aggregatum aggregatum* (Hill) gen. nov. UNE F8886, hypotype. Between 588 and 638 ft above the base of the Taemas Limestone, near Wee Jasper, N.S.W.
- FIG. 6, 9—*Embolophyllum asper* (Hill) gen. nov. (6) UNE F8911, hypotype, T.S.; (9) UNE F8914, hypotype, T.S. Both from 50 to 60 ft above the base of the Taemas Limestone, near Wee Jasper, N.S.W.

### PLATE 4

All figures  $\times 2$

- FIG. 1, 6—*Embolophyllum asper* (Hill) gen. nov. (1) UNE F8912, hypotype, T.S.; (6) UNE F8911, hypotype, T.S. Both from 50 to 60 ft above the base of the Taemas Limestone, near Wee Jasper, N.S.W.
- FIG. 2—*Embolophyllum aggregatum cracente* gen. et subsp. nov. UNE F8906, paratype 2, T.S. Between 443 and 448 ft above the base of the Taemas Limestone, near Wee Jasper, N.S.W.
- FIG. 3-5, 7-9—*Embolophyllum aggregatum aggregatum* (Hill) gen. nov. (3-5) UNE F8898, hypotype, T.S.; (7) UNE F8885, hypotype, L.S.; (8) UNE F8899, hypotype, L.S. (9) UNE F8898, hypotype, L.S. F8898 and F8899 are from 523 to 528 ft above the base of the Taemas Limestone, and F8885 is from between 588 and 638 ft above the base of the same limestone; all are from the Wee Jasper area of N.S.W.

### PLATE 5

All figures  $\times 2$

- FIG. 1, 3, 5—*Embolophyllum aequiseptatum bchanense* gen. et subsp. nov. (1) UNE F8928, paratype 5, T.S.; (3) UNE F8929, paratype 6, T.S.; (5) UNE F8923, holotype, T.S. All are from the Buchan Caves Limestone, near Buchan, Vict.

- FIG. 2, 4, 6, 7—*Embolophyllum aequiseptatum aequiseptatum* (Hill) gen. nov. (2) UNE F8936, hypotype, T.S.; (4, 6, 7) UNE F8920, hypotype, T.S. Both from the Cavan Limestone, near Wee Jasper, N.S.W.

## PLATE 6

All figures  $\times 2$

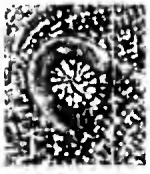
- FIG. 1, 2, 5, 7—*Embolophyllum aequiseptatum buehanense* gen. et subsp. nov. (1) UNE F8924, paratype 1, L.S.; (2, 5) UNE F8929, paratype 6, L.S.; (7) UNE F8928, paratype 5, T.S. All from the Buchan Caves Limestone, near Buchan, Vict.
- FIG. 3, 4, 6—*Embolophyllum aequiseptatum aequiseptatum* (Hill) gen. nov. (3, 6) UNE F8920, hypotype, L.S.; (4) F8935, hypotype, L.S. Both from the Cavan Limestone, near Wee Jasper, Vict.

## PLATE 7

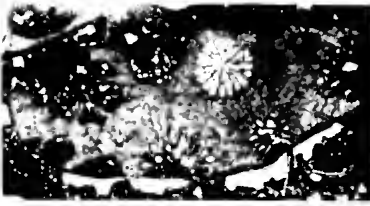
All figures  $\times 2$

- FIG. 1, 3—*Embolophyllum mundum* gen. et sp. nov. (1) UNE F8934, holotype, T.S.; (3) UNE F8934, holotype, L.S. Taravale Mudstone, Buchan, Vict.
- FIG. 2, 6—*Embolophyllum* (?) *mansfieldense* (Dun) gen. nov. (2) UNE F8932, hypotype, L.S.; (6) UNE F8932, hypotype, T.S. Coopers Creek Formation, Tyers R., Vict.
- FIG. 4, 5, 7—*Embolophyllum* (?) *mansfieldense* var. *secundum* nov. (4, 5) UNE F8881, hypotype regarded as type of the variety, L.S.; (7) UNE F8881, hypotype regarded as type of the variety, T.S. Loyola Limestone, near Mansfield, Vict.

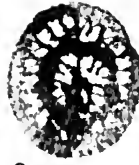




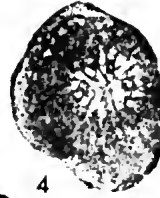
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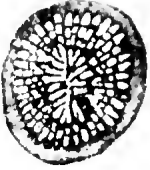
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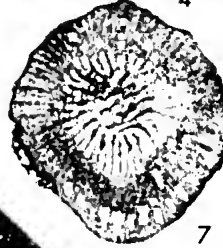
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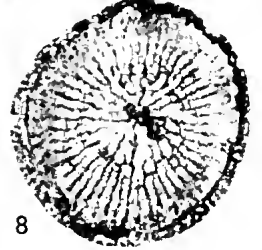
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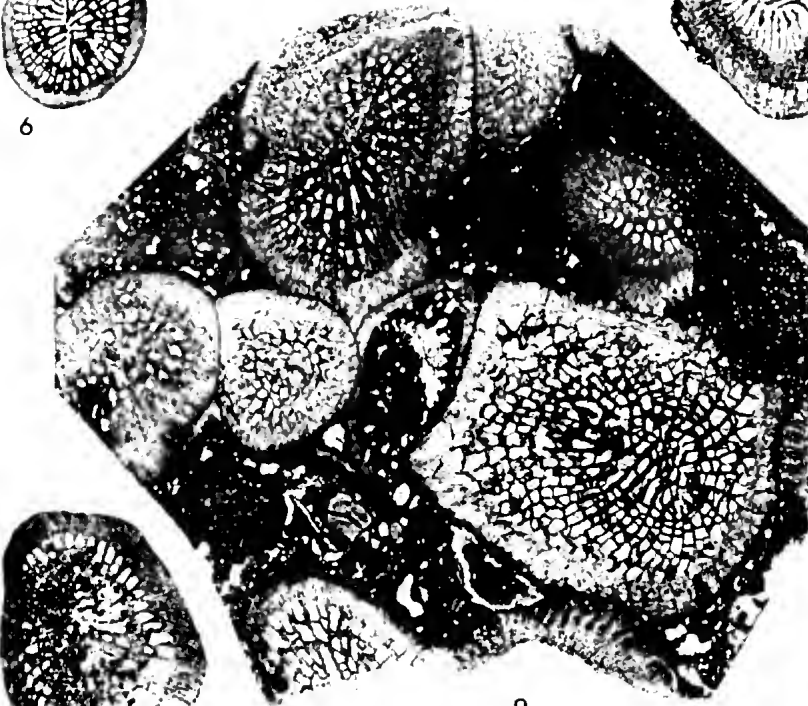
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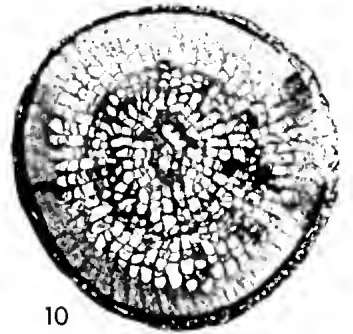
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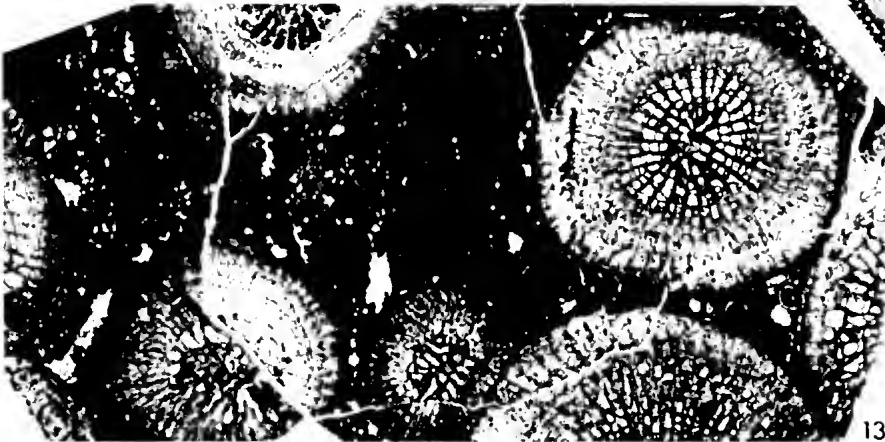
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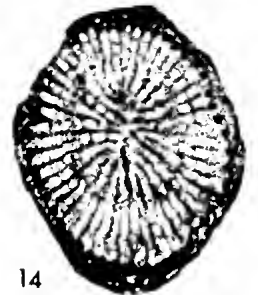
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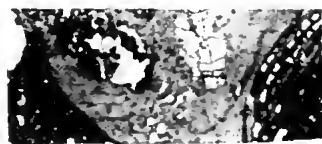
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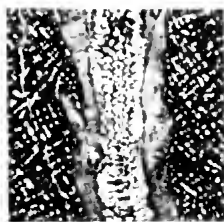
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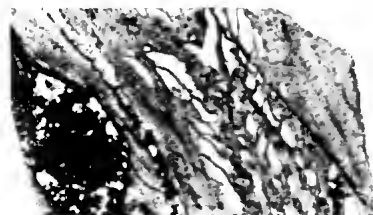
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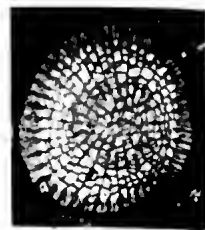
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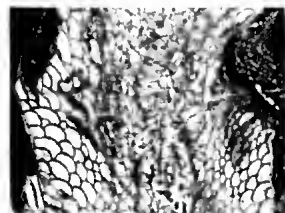
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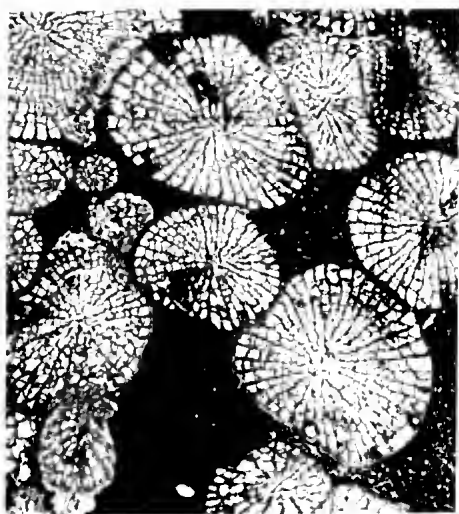
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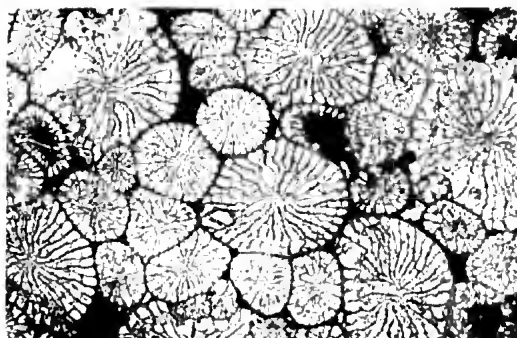
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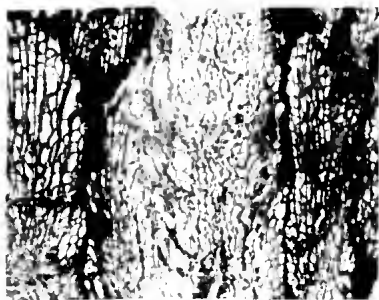
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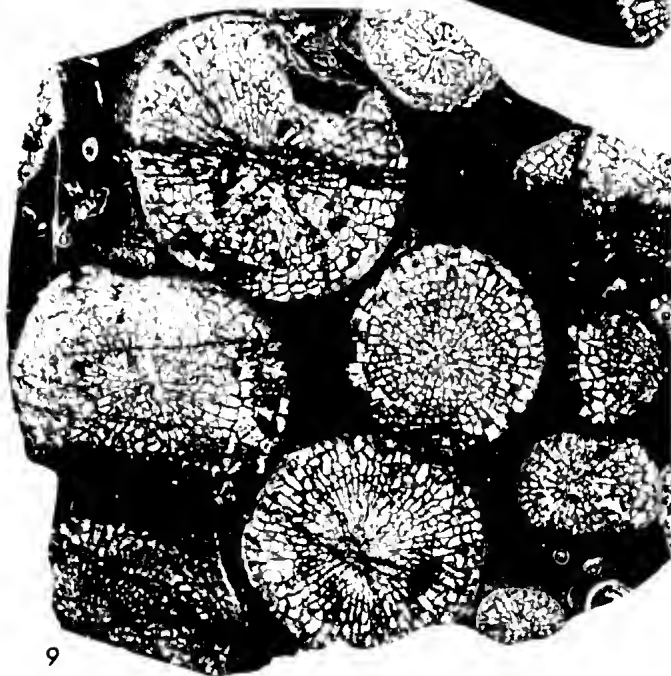
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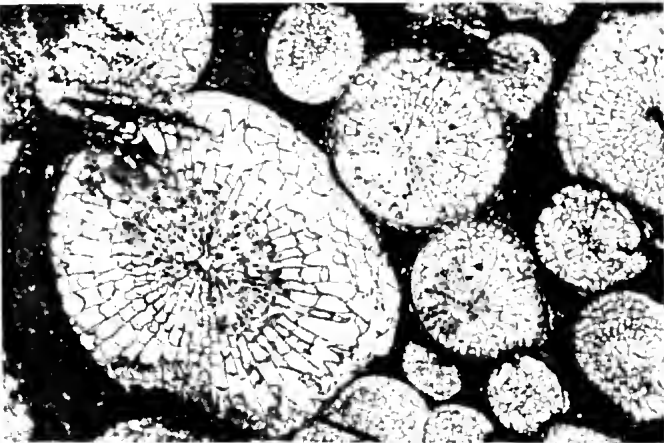


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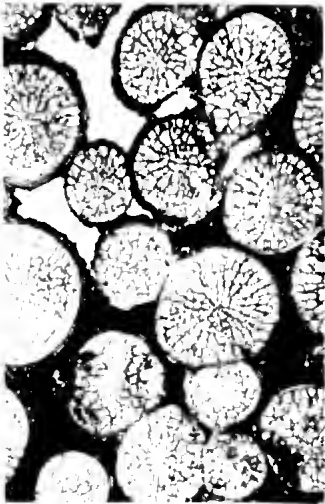


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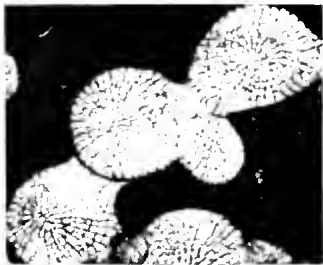




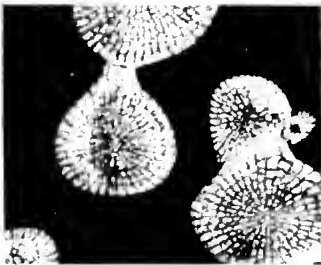
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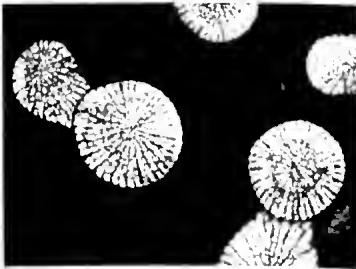
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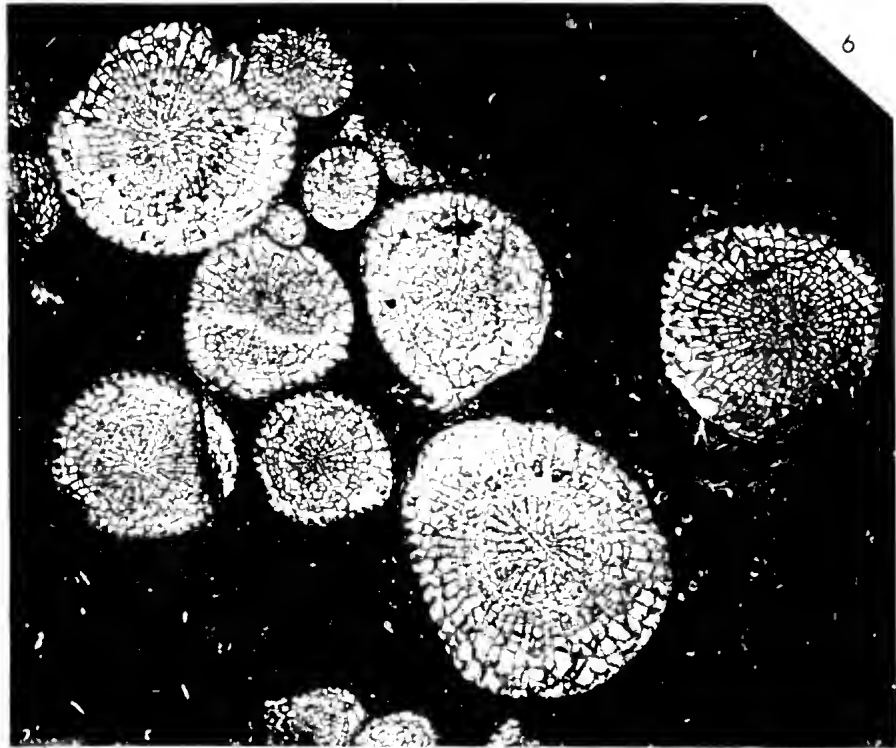
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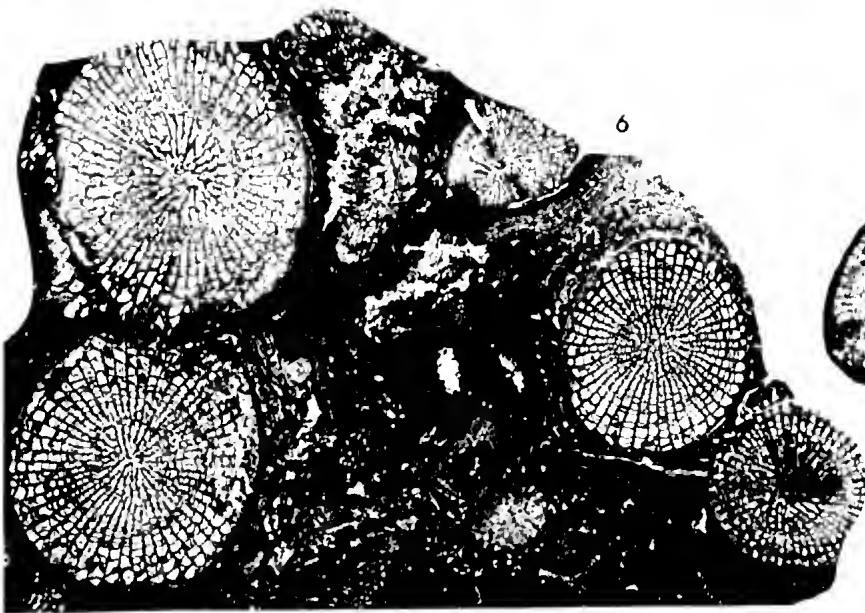
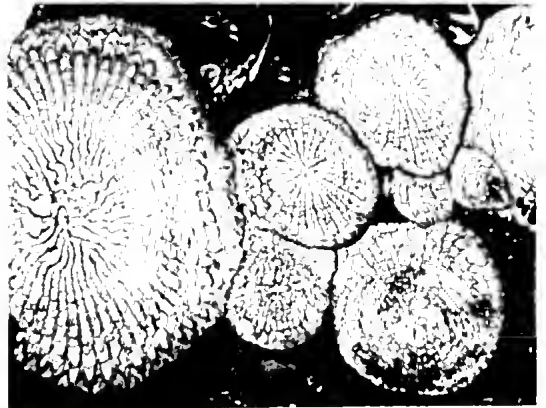
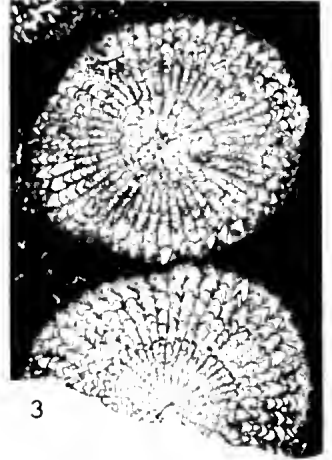
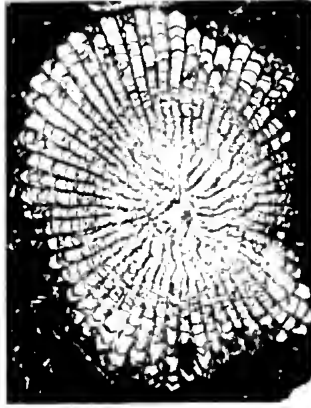
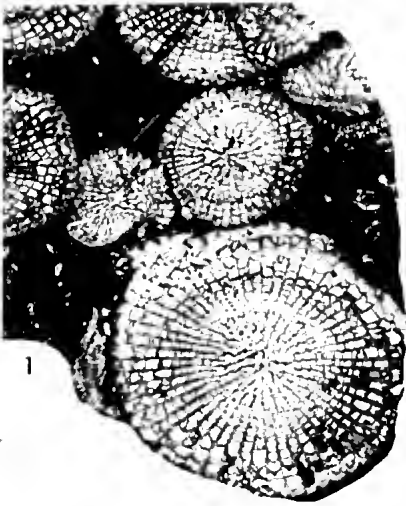


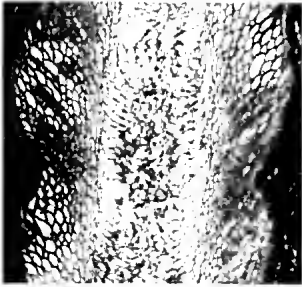
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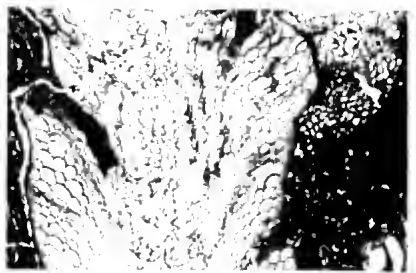




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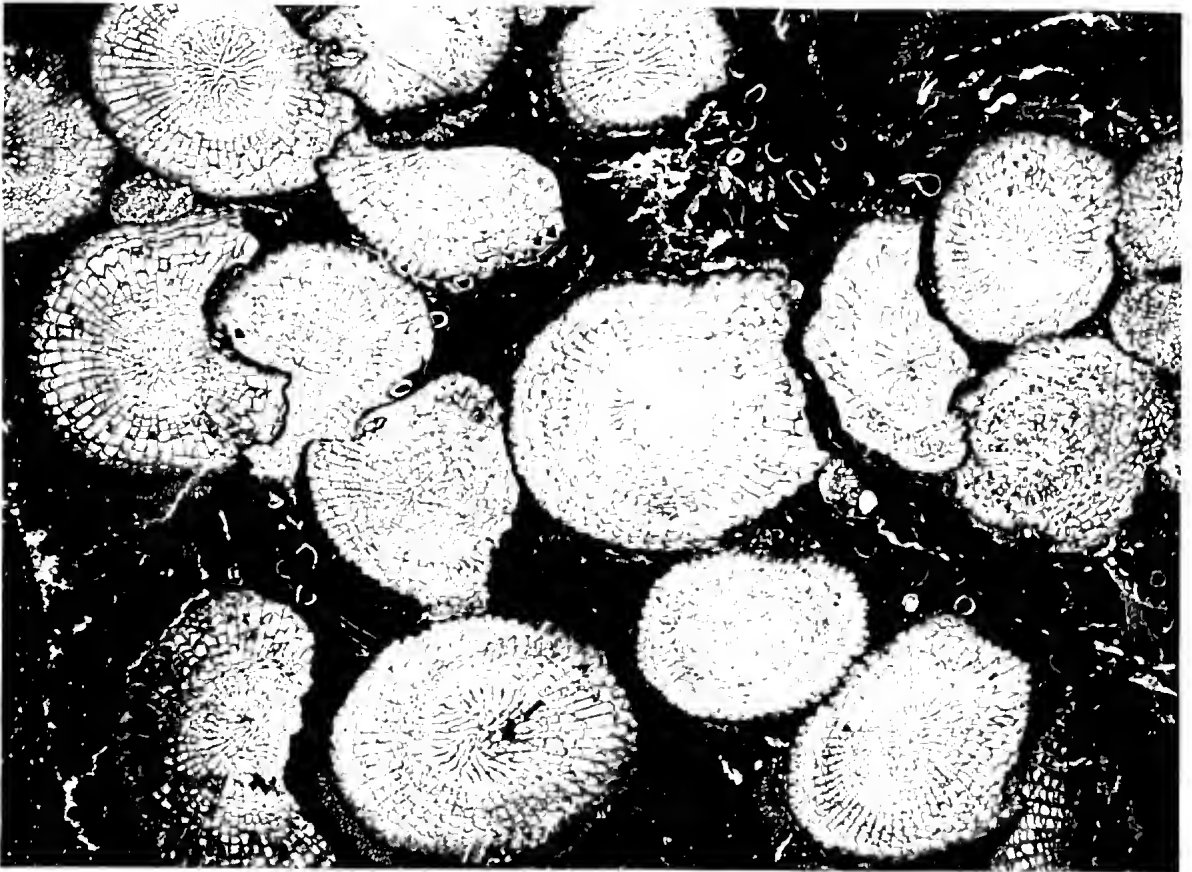


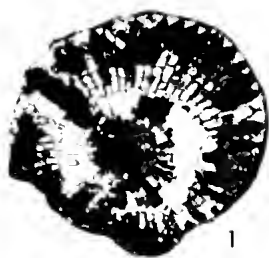
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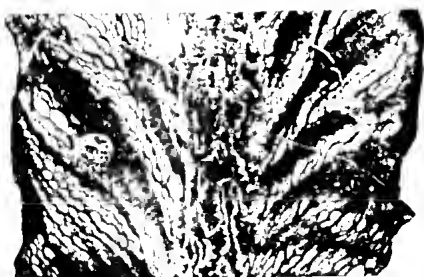
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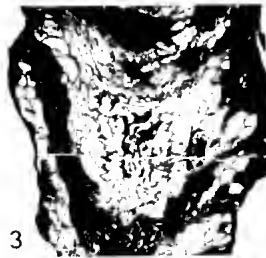




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# THE REDISCOVERY OF *HELEIOPORUS AUSTRALIACUS* (SHAW) (ANURA: LEPTODACTYLIDAE) IN EASTERN VICTORIA

by M. J. LITTLEJOHN and A. A. MARTIN

Zoology Department, University of Melbourne

## Introduction

In January, 1903, a specimen of *Heleioporus australiacus* (Shaw) (then known as *Philocryphus flavoguttatus*) from Tongio West, Vic., about 16 miles S. of Omeo, was exhibited by the National Museum of Victoria at the monthly meeting of the Field Naturalists Club of Victoria. This exhibition, and a comment on the uniqueness of the specimen by Mr J. A. Kershaw, were recorded in the published report of this meeting (Anon, 1903). It is presumably because of this indirect way of recording that the reference has been completely overlooked in the subsequent relevant literature, including the comprehensive bibliography on Australian Anura assembled by Moore (1961).

There is a single specimen of *H. australiacus* in the National Museum of Victoria (Catalogue No. 3293) from Tongio West, donated by J. Avery on October 29, 1907. It would seem that this specimen is the same as the one exhibited in 1903, but that there was some delay or error in recording the date of acquisition. There can be no doubt as to the identity of the specimen since this is a most distinctive species, and the specimen is in good condition. Until the present note, this information constituted the entire knowledge of *H. australiacus* in Victoria.

Moore (1961) has summarized the available information on the species and pointed out its peculiar distribution with two widely disjunct populations, one in the Sydney area, N.S.W., and the other in the Darling Range in southwestern W.A. Main (1965) briefly described the general biology and range of the southwestern populations of *H. australiacus*.

In January, 1963, while surveying the anuran fauna of coastal N.S.W., we had the good fortune to obtain a single specimen of *H. australiacus* and a recording of its mating call at Jervis Bay, about 2 miles NW of the Naval College. Two others were heard in the area but were not collected. The one specimen subsequently escaped, but not before it had been adequately photographed.

On December 6, 1965, while engaged in further survey work, we obtained three more specimens of this species on the road from Bombala, N.S.W., to Cann River, Vic. The first of these was collected 25 miles S of Bombala (about 5 miles N of the Victorian border). The second and third specimens were collected in Victoria, 200 and 300 yards, respectively, south of the border (i.e. about 29 miles N of Cann River). These two individuals were breeding males, and tape recordings of their mating calls were made before they were collected. In addition, the calls of another three individuals were heard in the area, and one of these was recorded.

On February 23, 1966, one of us (A.A.M., assisted by Mr P. A. Rawlinson) collected two more male *H. australiacus* 2½ miles N of Boola Camp, i.e. about 7 miles S of Walhalla, Vic. On this occasion egg masses of this species were also found, and these will be reported on later.

The occurrence of *H. australiacus* in Victoria is thus established beyond doubt, and in fact the westward penetration of this species into Victoria is much greater than was previously supposed. Our records indicate that *H. australiacus* probably has a continuous range from the Sydney area, N.S.W., to the Walhalla area, Vic.

Main (1965) has indicated that Dr A. K. Lee, of the Department of Zoology and Comparative Physiology, Monash University, using morphological criteria, considers that the southeastern and southwestern populations of *H. australiacus* are specifically distinct, and will describe the latter as a new species in due course. Accordingly, an objective comparison of mating call structure of the southeastern and southwestern disjuncts has been made, as it may be of some assistance in assessing the degree of potential premating reproductive isolation.

Littlejohn and Main (1959) described the mating call of the southwestern population and figured an audiospectrogram of a call. An oscillogram of a call is given by Littlejohn (1965a). Since the mating call of the southeastern population has been described only in general and quite subjective terms (Harrison, 1922; Moore, 1961), an objective and relatively complete description is given herewith, together with observations on adult morphology, habitat, food, and calling behaviour.

#### Adult Morphology

Our specimens (one of which is shown in Pl. 8, fig. 1) agree closely in morphology with the description given by Moore (1961). The three animals collected on the Cann River road have body lengths of 80.4, 86.0, and 89.9 mm, and tibia

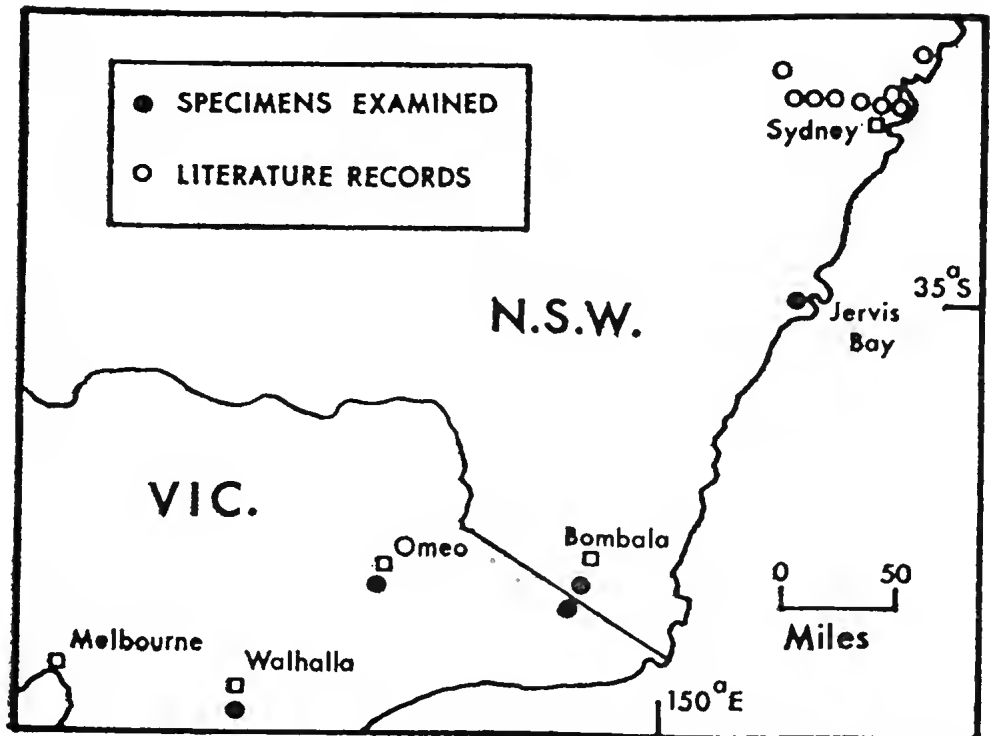


FIG. 1—The known distribution of *Heleioporus australiacus* in southeastern Australia. The literature records are from Moore (1961).

length/body length ratios of 0.37, 0.35 and 0.35, respectively. All three have the large, black nuptial spines on the first three fingers well developed (Pl. 8, fig. 1; and also see Moore, 1961, p. 180, Fig. 9). These spines, together with the animal's large size, spiny dorsal skin texture, bright yellow lateral warts, and pinkish ventral surface, make *H. australiacus* a most distinctive and unmistakable species.

### Habitat

The three Cann River road specimens were collected in an area of dense wet sclerophyll forest. The two calling males were found in a shallow creek lined by a stand of tree-ferns. The creek flows through a deep gully, with earth banks and a sandy bottom, and scattered rock outcrops. One male was calling from a large, partially-flooded burrow in the soft earth at the base of the bank. The other was in a more open position in the middle of a small pool, partly concealed by a mass of plant detritus.

The Jervis Bay specimen was also calling from a burrow in the bank of a rivulet, in an area of coastal heath with scattered eucalypts. Two more individuals, which we did not collect, were calling in a more heavily forested area.

### Food

Since the feeding habits of *H. australiacus* are apparently unrecorded, the following may be of interest. A faecal pellet of the specimen collected 25 miles S of Bombala contained remains of:

ARACHNIDA: small buthid scorpion, large arancomorph spider.

DICTYOPTERA: two cockroaches.

HEMIPTERA: reduvioid bug.

HYMENOPTERA: two large ants.

COLEOPTERA: numerous carabids, one scarabaeoid, one cureulionid, and some unidentified material.

### Mating Call Structure

The mating call of the eastern disjunct of *H. australiacus* may be described as a short, soft, musical, pulsed note, regularly repeated in long sequences. Moore (1961) has given an adequate verbal description of the call: 'a soft, owl-like "ou-ou-ou".' Our tape recordings, obtained in the field, were analysed on a cathode ray oscilloscope and a sound spectrograph (Kay Sona-Graph Model 6061 A), giving the following physical characteristics, which are summarized in Table 1.

TEMPORAL CHARACTERISTICS: The call, which is repeated about 18-24 times per minute, has a duration of just over half a second. The envelope is overmodulated so that the call consists of 5-7 discrete pulses, each of 50-60 milliseconds duration, and separated by a slightly longer pulse interval (silent period between the end of one pulse and the beginning of the next) of about 70-80 milliseconds. The pulse repetition rate ranges from 7.6 to 10.7 pulses per second, and the rise and fall in amplitude of each pulse is gradual.

SPECTRAL CHARACTERISTICS: Most of the energy is contained within a low fundamental frequency (320-390 cycles/second) which is thus also the dominant frequency of the call. Two to four additional harmonics of reduced energy content are also present. No pronounced frequency modulation is evident.

An oscillogram and an audiospectrogram of a call are shown in Pl. 8, fig. 2.



TABLE 1

Physical characteristics of mating calls of *Heleioporus australiacus*. Data for each individual are based on the analysis of 3 calls, and only mean values are given since there is very little variation in the successive calls of an individual.

	29 miles N. of Cann River, Vic.			Jervis Bay, N.S.W.
Individual No.	1	2	3	1
Water temperature, °C	14.4	15.0	15.6	18.5
Wet bulb air temperature, °C	15.0	—	14.3	16.0
Call duration (seconds)	0.58	0.59	0.53	0.53
Pulses per call	5	7	5	6
Pulse repetition rate* (pulses/second)	7.6	10.7	8.3	10.6
Call repetition rate (calls/minute)	18.3	20.5	21.5	23.5
Fundamental (dominant) frequency (cycles/second)	340	320	360	390

\* Determined from the formula:

No. of pulses—1

Total call duration—duration of first pulse

### Comparison with the Mating Call of the Southwestern Disjunct

Littlejohn and Main (1959) listed an approximate fundamental frequency of 200 cycles/sec. for the mating call of one individual from Greenmount, W.A. A recalculation from an oscillogram of a call in the same recording sequence gave a value close to 340 cycles/sec. The lower reading in the earlier reference was obtained from a sound spectrograph tracing and the difference may be due to the width of the baseline in such tracings (which has a considerable influence on the assessment of correct values of these very low audio frequencies).

The call of the western individual (which is fairly representative of the disjunct) differs slightly from those of the eastern disjunct in having a shorter call duration and in being more rapidly repeated. It differs markedly in that it lacks the pronounced amplitude modulation which is so strikingly expressed in the eastern calls. This qualitative difference is of such magnitude that, on the basis of comparisons of calls of closely related sympatric species of anurans (Littlejohn, 1965b), we might expect the calls to operate as effective premating isolating mechanisms should the two populations ever become sympatric. This finding gives further support to the conclusion made by Dr Lee, on the basis of their morphological differentiation, that the disjuncts have achieved species status.

### Acknowledgements

This investigation was supported by a research grant from the Nuffield Foundation. Sound analysing apparatus was provided by the University of Melbourne research grants to the Zoology Department. The National Museum of Victoria kindly provided information on the Tongio West specimen.



## References

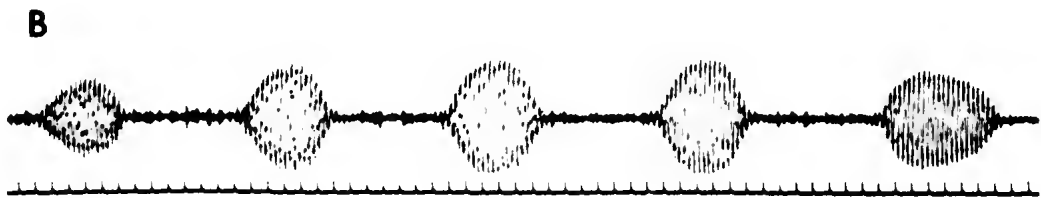
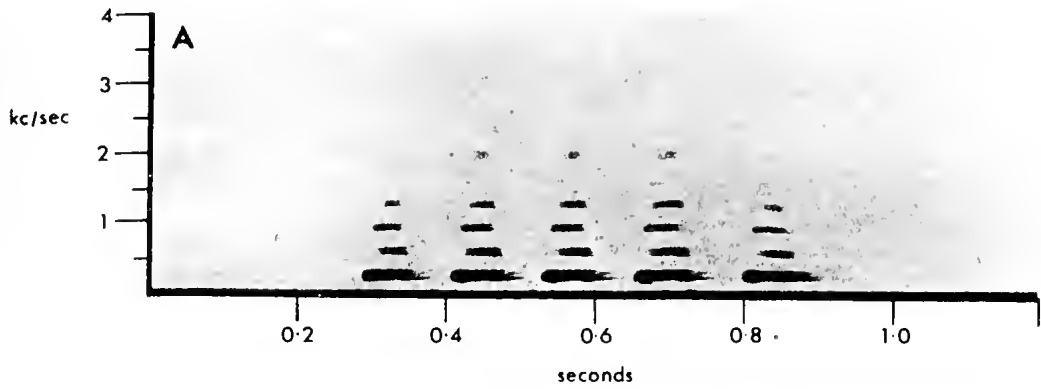
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## Explanation of Plate

## PLATE 8

- FIG. 1—Adult male specimen of *Heleioporus australiacus* from 29 miles N. of Cann River, Vic.  
FIG. 2—A, an audiospectrogram, and B, an oscillogram of a call of *Heleioporus australiacus*, recorded 29 miles N of Cann River, Vic. The time marker in the lower trace indicates 0.01 second intervals.







THE INFLUENCE OF DIAPAUSE ON THE RESISTANCE TO  
DESICCATION OF EGGS OF *TELEOGRYLLUS COMMODUS*  
(WALK.) (ORTHOPTERA: GRYLLOIDAE)

by T. W. HOGAN

Victorian Plant Research Institute, Department of Agriculture,  
Swan Street, Burnley, Victoria

**Abstract**

The eggs of two races of *Teleogryllus commodus*, one a non-diapausing race from a tropical latitude and the other from a temperate zone of Australia, were measured at each of two stages of development for resistance to desiccation. A comparison was also made between eggs in diapause and those at a similar stage of development from the same cricket cultures, from which diapause had been eliminated by prior treatment with ammonia.

It was found that eggs of both races were much more sensitive to desiccation prior to water uptake. The most resistant eggs were from the non-diapausing race after water uptake had been completed.

Diapausing eggs were more resistant than eggs of the same source from which diapause had been eliminated; but since eggs at a similar stage of development from a non-diapausing race were even more resistant, it would appear that the enhanced resistance may be incidental to, rather than a function of, diapause.

**Introduction**

One of the functions attributed to diapause is that in addition to being a means by which the life cycle is synchronized with the seasonal cycle, it confers on the diapausing organism 'an enhanced resistance to adverse climatic conditions such as cold, heat and drought' (Lees 1955). This implies that there are physiological changes accompanying the onset of diapause having the specific effect of rendering the organism more resistant to unfavourable conditions.

Despite the general acceptance of this viewpoint, there seems to be an absence of any reported experimental work demonstrating that organisms in diapause are more resistant than similar organisms in the same stage of development, but diapause-free. One reason for this is that direct evidence as to whether increased resistance due to physiological change is a concomitant of diapause is difficult to obtain in an organism with obligate diapause, since the most acceptable comparison is between diapause and non-diapause material tested contemporaneously. Thus the fact that in *Petrobia lutea* the winter diapausing egg has an additional layer of wax in the cuticle compared with the summer egg and is more resistant to desiccation (Lees 1954) does not constitute critical evidence, since presumably this could be a characteristic of the winter egg independently of diapause.

However, in *Teleogryllus commodus* it has been found that the application of ammonia under specified conditions eliminates diapause (Hogan 1964). It is possible, therefore, to compare eggs from the same cricket culture, and from the same egg batches, some of which have had diapause induced in them, and others from which diapause has been averted.

In this paper an experiment is described in which the relative capacity to resist desiccation of diapausing and non-diapausing eggs from the same source and at a similar stage of development is measured. As a further measure of the degree of

resistance to desiccation in non-diapausing eggs, observations were made on the eggs of a non-diapausing race of *T. commodus* from northern Queensland. Finally, eggs of both races were tested at an earlier stage of development, prior to the stage at which water uptake occurs. This commences on the third day of development at 27°C, and is described by Browning (1953) who also studied the effect of desiccation.

### Materials and Methods

Eggs from laboratory-reared progeny of crickets collected from the field were obtained by placing trays of moist sand into the cultures overnight and sieving out the eggs the next morning (Hogan 1965). Desiccation experiments were performed on batches of approximately 1000 eggs in each of the following categories.

- (1) Eggs of the diapause race at the pre-diapause, pre-water uptake stage. These eggs had been incubated for three days at 23°C, commencing within eight hours of oviposition.
- (2) Diapause eggs. Diapause had been induced by incubating the eggs at 23°C for a period of 12 days.
- (3) Diapause-free eggs. Diapause had been averted by treating 3-day old eggs (at 23°C) with gaseous ammonia evolved from 100 mls. of 0.032M  $\text{NH}_4\text{OH}$  in a desiccator for a period of four days. The eggs were then washed and transferred on to water-soaked filter paper discs in plastic tubes and incubated at 18°C for a further four days and one day at 23°C, by which time water uptake had been completed in all the eggs. (Uptake of water appeared to be delayed to some extent by the ammonia treatment).
- (4) Eggs of the non-diapausing northern Queensland race at the pre-water uptake stage similar to (1).
- (5) Eggs of the northern Queensland race which had been incubated for eight days\* at 23°C, by which time water uptake was complete. (The embryos would be more advanced than those of diapause eggs of the same age, which stop development just prior to water uptake).

\* Water uptake takes place at this stage both in non-diapausing and diapausing eggs; but the latter require a further period to be in full diapause (Hogan 1960).

### DESICCATION

The desiccation of the eggs was carried out in a 10" desiccator modified for the purpose by replacing the glass-domed top with a flat piece of perspex from which was suspended a 6"  $\times$  4" bronze gauze tray. This held small gauze wire trays in which the eggs for testing were placed. To enable these trays of eggs to be placed in and removed from the desiccator at the appropriate times, the perspex cover was fitted with a 2"  $\times$  4" opening covered by another piece of perspex sealed with petroleum jelly. This cover would slide aside when necessary with a minimum of disturbance to the air in the desiccator. Controls for each type of egg were held under the same conditions during the desiccation treatment but with water in the desiccators, and were then incubated on moist filter paper in tubes at 23°C to determine natural mortality.

The relative humidity was controlled by a sulphuric acid of SG 1.830 in the well of the desiccator. Variations in the R.H. were measured by means of a small, previously calibrated hair hygrometer suspended from the perspex cover. The desiccator was on a turntable rotating at 5 r.p.m. in a cabinet held at 18° ( $\pm$  0.2°)C.

The trials were carried out at 18°C because at this temperature the rate of development of the eggs is very low and there would be little change in stage of development of eggs not in diapause during the period of treatment.

The more critical comparisons of the diapause, diapause averted, and non-diapausing eggs, were carried out synchronously on eggs of the same batch; eggs at the pre-water uptake stage were tested separately but under identical conditions to the other stages.

Three replicates of 50 eggs for each treatment were counted into the gauze wire trays and placed in the desiccator. One set of replicates for each type of egg was removed after 6, 16 and 32 hours and for types 2 and 5, also after 42 hours (see Section II). These periods of exposure to desiccation were based on preliminary experiments.

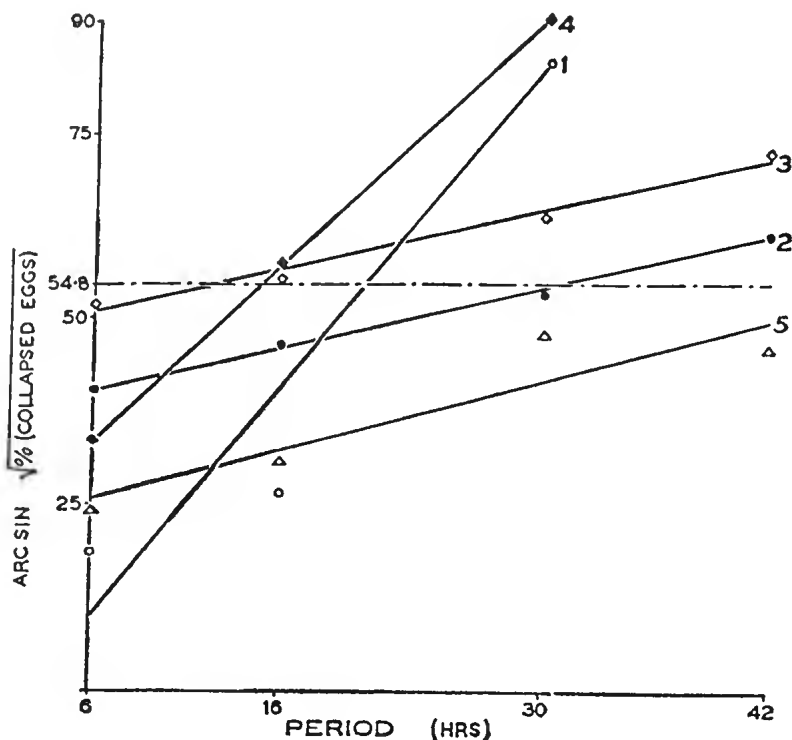


FIG. 1—The resistance to desiccation of five types of eggs of *Teleogryllus commodus* expressed as the arcsin percentage of eggs that collapsed in the period of exposure indicated on the abscissa. The types of eggs are as follows: (1) Pre-water uptake—diapausing race; (2) Diapausing (3) Diapause-free (4) Pre-water uptake, non-diapausing race (5) Water uptake, non-diapausing race.

For more precise details, see 'Materials and Methods', p. 38.

The effect of desiccation on the eggs at each interval of time was measured by counting in each group the number of eggs that completely collapsed as a result of the treatment. In previous tests all such eggs had been found to be dead when incubated at 23°C in the presence of moisture. Browning (1953) found that very few eggs were able to survive a 20 per cent loss by weight of moisture.

### Results

During the course of the experiment, the R.H. varied from 1.5—5 per cent, the increases being associated with opening of the desiccator at the above intervals. Over the initial six hours, the mean R.H. was slightly lower than over the other periods but this applied to each type of egg and, if it has any significance at all, affects only the comparison between the effect of periods of treatment.

Fig. 1 shows that the stage of development was important in relation to the ability of the eggs to resist desiccation; the mean period for the collapse of the pre-water uptake eggs was significantly less than for the post-water uptake eggs of both the diapause and non-diapause races.

The diapausing eggs were significantly more resistant than diapause-free eggs of the same race, but these same diapausing eggs were significantly less resistant than the non-diapausing eggs, at a corresponding stage of development, from the Queensland race. It is clear, therefore, that the attribute of resistance to desiccation can exist quite independently of diapause.

In the control treatments the ammonia-treated Victorian eggs proved to have 20 per cent of the eggs in diapause. Presumably this would have the effect of giving this group a resistance to desiccation higher than if all of them were diapause-free.

### Discussion

The greater susceptibility of the pre-water uptake stage of the eggs of both races to desiccation is not surprising if one considers the conditions under which this stage normally occurs. The mature females have the characteristic that they avoid ovipositing in dry soil and oviposition is usually delayed until adequate rain has fallen. Freshly oviposited eggs, therefore, are assured of an adequate moisture supply during the early stages of development. Adaptive selection for resistance to desiccation on pre-water uptake eggs would operate to a very limited extent, if at all.

Mature females of the Queensland race show the same aversion to ovipositing in dry sand when reared in laboratory cultures. Presumably, water uptake, in the field, is assured in the same way as in the Victorian race.

At the other extreme, eggs from the Queensland race, when water uptake is complete, are much more resistant to desiccation. Again, this appears to be in accordance with the conditions they may experience. Should drought occur in the tropics, then it would be expected that the prevailing high temperatures would lead to severe desiccating conditions. Victorian eggs at this stage of development may experience drought conditions too, but the temperatures would be lower and in the late autumn, cool nights would lead to condensation of moisture from the air so that conditions would be relatively moderate.

When comparing the resistance to desiccation of the pre-water uptake eggs and the post-water uptake eggs, it must be taken into account that the former have a smaller volume, less water and a relatively larger surface area. Hence, if the permeability of the cuticle were the same in both types of eggs, those at the pre-water uptake stage would be expected to collapse more rapidly.

The results obtained with the non-diapausing race from northern Queensland demonstrate that adaptation for resistance to desiccation in eggs of *T. commodus* is possible without involving diapause, and this provides some evidence to support the idea that the function of diapause in the Victorian eggs is primarily to synchronise the life cycle of the insect with the climatic cycle of the seasons.

Nevertheless, the foregoing results show that when diapause is eliminated, eggs of the Victorian race are more susceptible to desiccation. It is apparent, therefore, that there must be physiological changes in the eggs accompanying the entry into



diapause that confer increased resistance to desiccation. Since, however, resistance to desiccation is high in eggs of the non-diapausing race, it is concluded that the extra resistance associated with diapause is incidental to, rather than a function of, diapause.

Salt (1961) has reached a similar conclusion in relation to cold hardiness and diapause. In his opinion, cold hardiness due to the accumulation of glycerol in the blood, though acquired concurrently with the entry into diapause, is not causally related to it.

### Acknowledgements

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# MURIFERELLA, A NEW GENUS OF LOWER DEVONIAN SEPTATE DALMANELLID

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## Abstract

*Muriferella* is proposed as a new genus of septate dalmanellid known from the late Lower Devonian of southeastern Australia, Nevada, and Arctic Canada. The new genus belongs to the Schizophoriidae and was derived from the widespread Silurian to Lower Devonian draboviinid genus *Salopina*. A new species, *Muriferella masurskyi*, from the Cortez Mountains of central Nevada, is described and selected as type species of *Muriferella*. A previously named species, *Phragmophora punctata* Talent, from the Emsian of Victoria, southeastern Australia, is assigned to the new genus.

Septate dalmanellids are a polyphyletic morphologic group as indicated by the presence of septate brachial valves recognized in several distinct dalmanellid lineages. Septation is not recommended as a basis for suprageneric taxonomy.

## Introduction

Small septate dalmanellid brachiopods compose a relatively uncommon morphologic group of shells that have most commonly been recorded from rocks of Middle and early Upper Devonian age; the amount of available information regarding their distribution and phylogenetic relations has been inconsequential with the exception of Cooper's valuable contribution (1955). The first septate dalmanellids older than Middle Devonian were described by Havlíček (1953) under a new generic name *Prokopia*. The first Australian Lower Devonian septate dalmanellids were described more recently by Talent (1963, p. 60) as *Phragmophora punctata*. At the time it was clear that Talent's specimens did not belong to *Phragmophora* in the strict sense and the various points of difference were enumerated (Talent 1963, p. 61), but the scarcity of well preserved material together with the general lack of information about septate dalmanellids dictated a conservative approach.

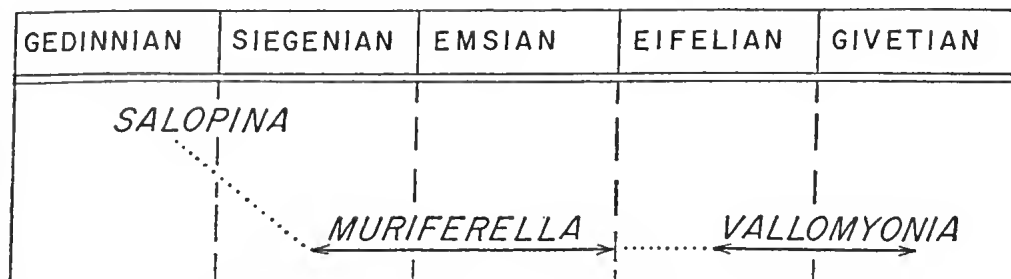


FIG. 1—Range and suggested derivation of *Muriferella* and *Vallomyonia*.

During the course of study of large septate dalmanellids described elsewhere by the writers under a new subfamily name Cortezorthinae (Johnson & Talent 1967), small septate dalmanellids were discovered in the Lower Devonian of central Nevada and the Canadian Arctic that are congeneric with Talent's '*Phragmophora punctata*'. The new generic name *Muriferella* is now proposed for this taxon which proves to be a derivative of the widespread small aseptate dalmanellid *Salopina*, most common in the Silurian and Lower Devonian.

### Systematic Palaeontology

#### PHYLUM BRACHIOPODA

#### Suborder DALMANELLOIDEA

#### Superfamily ENTELETACEA Waagen, 1884

#### Family SCHIZOPHORIIDAE Schuchert & Le Vene, 1929

#### Subfamily DRABOVIINAE Havlíček, 1950

#### Genus *Muriferella* n. gen.

TYPE SPECIES: *M. masurskyi* n. sp.

DIAGNOSIS: Like *Salopina* but with a long, low median septum in the brachial valve.

DISCUSSION: *Muriferella* is a small unequally biconvex dalmanellid with a sulcate brachial valve and with hollow radial costellae on the exterior. Internally there are well developed dental lamellae enclosing a short, triangular, ventral muscle scar. The brachial valve bears elevated cylindroidal sockets floored by fulcral plates. The brachiophores are connected by supporting plates to the base of the valve as in *Salopina* although they commonly diverge a little more anteriorly than is common in *Salopina*. This is not surprising since in the probable ancestor of *Salopina*, *Fascifera*, as well as the closely allied genus *Pionodema* (Boucot, Johnson, & Walmsley, 1965, p. 332), the tendency for strong anteriorly divergent brachiophore supporting plates is better developed than in younger forms assigned to the Draboviinae. The cardinal process is simple to bilobed and is situated on a notothyrial platform that may be a thick callosity, or which may consist essentially of ancillary struts. A median septum originates at about the base of the cardinal process and extends to the anterior margin or nearly so, but is not high and triangular. All of the specimens investigated show only a slight increase in height of the median septum in the anterior direction.

COMPARISON: *Muriferella* differs from most Draboviinae, including *Salopina*, to which it is closest morphologically, by the presence of a median septum. Some species of *Salopina*, such as *Salopina* cf. *crassiformis*, develop a long, low median ridge that may reach to the anterior margin (Pl. 9, fig. 15), but many free brachial valves of this species in a number of collections in Nevada show considerable variation in the length and strength of the ridge. None develop the proportions of a septum, i.e. with the height two to three or more times the width of the structure. All other septate dalmanellids known at the present writing bear high triangular median septa which at once distinguishes them from *Muriferella*. In addition, *Prokopia* Havlíček and *Phragmophora* Cooper differ further by lacking fulcral plates. *Monelasmina* Cooper (1955, Pl. 11D), which resembles *Muriferella* to some extent, has a high triangular median septum, but differs in addition by having relatively long, bilobate, diductor impressions in the pedicle valve. *Hypsomyonia*, *Kayserella*, and *Mystrophora* all have elevated muscle platforms or cruralia in the brachial valve unlike the simple muscle bounding ridges around the dorsal adductor

sears of *Muriferella*. The septate dalmanellid that appears closest to *Muriferella* is the recently proposed *Vallomyonia* Johnson (1966, Pl. 23, figs. 1-17), but *Vallomyonia* bears a high, triangular median septum. Furthermore, its dental lamellae are very small, thin, and apparently incipient. In addition the fuleral plates are mere vestiges seen in the smallest specimens and very difficult to detect in larger ones. In addition, the dorsal muscle pattern, which in small specimens is essentially identical with that of *Muriferella*, differs in larger ones the size of larger specimens of *Muriferella* (e.g. Pl. 9, fig. 6) by having scalloped, somewhat elevated margins, something that is not developed in *Muriferella*.

**PHYLOGENY:** Because of the very close internal and external resemblance of *Muriferella* to *Salopina*, especially the well developed fuleral plates and brachio-phore supporting plates and the typical hollow costellae that are known in *Salopina*, there appears to be a high probability that *Muriferella* was derived from *Salopina*. The stratigraphic relations support this conclusion since *Salopina* is common throughout the Silurian and extends at least as high as the Siegenian in the Lower Devonian. Among the younger species of *Salopina* there is the abundant occurrence of *Salopina* cf. *crassiformis* in the Gedinian in Nevada (Pl. 9, figs. 15-27) which commonly has a long median ridge in the brachial valve that may extend even to the anterior margin, and long subparallel adductor bounding ridges, two features that especially characterize Kozłowski's species. Among the species known to the writers at present, through the investigations of Walmsley, Boucot, and Harper (in prep.), *Salopina crassiformis* appears to be the most logical ancestor for *Muriferella*.

Morphologic comparisons and stratigraphic occurrence also support the probability that *Muriferella* gave rise to *Vallomyonia*, probably some time in the Eifelian; the latter genus occurs in the Eifelian and lower Givetian in central Nevada. The development of *Vallomyonia* is accompanied by reduction in the size of the dental plates and by increase in the height of the median septum to a large, triangular, blade-like structure. In addition, the dorsal adductor muscle bounding ridges tend to become relatively prominent in the brachial valve of *Vallomyonia*.

As pointed out by Johnson (1966, p. 159), *Vallomyonia* may be the ancestor of *Hypsomyonia* Cooper. In fact the two genera differ essentially by the full development of elevated muscle bounding ridges to form a somewhat platform-like structure in the brachial valve.

Wright (1965, p. H339) proposed the family Hypsomyoniidae to include the single genus *Hypsomyonia* Cooper, thus isolating it from other septate dalmanellids, but without a discussion of phylogeny to indicate probable relations. In view of the synthesis proposed by the writers to represent the phylogeny of *Salopina Muriferella*, *Vallomyonia*, to *Hypsomyonia*, it appears that Hypsomyoniidae should be discarded in favor of inclusion of *Hypsomyonia* in the Draboviinae. The nomenclatural simplification attending this proposal seems desirable since the development of a median septum is certainly polyphyletic. It appears to have arisen at least twice in the Draboviinae, i.e., once in *Monelasma* which possibly originated independently out of *Salopina*, or more likely out of *Sphenophragmus* as noted by the writers elsewhere (Johnson & Talent, 1967). A median septum is present in a dalmanellid closely allied to *Resserella* in the Silurian in specimens shown to us and being described by Norman Savage and by C. W. Harper. We have elsewhere described a lineage of isorthid brachiopods that developed a median septum some time in the Early Devonian; these have been assigned to the new subfamily Cortezorthinae embracing both septate and aseptate dalmanellids originating in the Silurian. Furthermore, at the moment, we see no really close association between the group under discussion here and either *Prokopia* and *Phragmophora* or *Kaysarella* and

*Mystrophora*. It appears therefore that the median septum in dalmanellids was derived independently three or four times in the Silurian and Devonian.

The muscle platform of *Hypsomyonia* is certainly not a unique feature since variations of it are also present in *Kayserella* and in *Mystrophora* and in a new genus from the Lower Devonian of New South Wales, related to the latter two, shown to us by Norman Savage. Furthermore, consideration of phylogeny tends to diminish the importance of this character.

It is anticipated that as our knowledge of septate dalmanellids in the Silurian and Devonian increases, the proposal of subfamilies and families for what now appear to be aberrant structures would require numerous relatively ineffectual divisions of several distinct lineages, principally in the Lower and Middle Devonian. For this reason we recommend inclusion within the Draboviniac of the lineage culminating in *Hypsomyonia*.

**DISTRIBUTION:** Both species described here, *Muriferella masurskyi* and *Muriferella punctata*, are from the Emsian, from Nevada and Victoria respectively. In addition, Johnson has seen specimens sent by Dr Alfred C. Lenz from the *Mouograptus yukonensis* zone of probable late Siegenian age (Boucot, *et al.*, 1966). The *yukonensis* zone specimens are very small, not reaching a size commonly seen in *M. masurskyi*, and have relatively strongly convex brachial valves that contrast with the somewhat flatter ones of *M. masurskyi*, but in internal characters the two are very similar. Johnson has also seen specimens in two collections (GSC locs. 59036 & 67145) made by Dr J. W. Kerr from near the top of the Stuart Bay Formation on east-central Bathurst Island in the Canadian Arctic. Thus the known geographic range of *Muriferella* extends in an arc around western North America from Nevada to the Arctic Islands, plus an occurrence in Australia. The North American distribution is very similar to that of a number of other Lower Devonian genera studied by Johnson, such as septate members of the Cortezorthinae (Johnson & Talent, 1967), the pholidostrophiid *Phragmostrophia* (Harper, Johnson, & Boucot, in press), and the chonetid genus *Parachonetes* (Johnson, 1966b). The range of the septate cortezorthinids and *Phragmostrophia* also extends to Novaya Zemlya as noted in the papers cited above. *Parachonetes* has a broader range, is also present in Australia and at numerous Lower Devonian localities in eastern Europe and Asia, so the occurrence of *Muriferella* in Australia may indicate a somewhat broader distribution pattern more like that of *Parachonetes*. The cortezorthinid dalmanellid *Reeftonia* and the pholidostrophiid *Nadiastrophia*, both described and illustrated earlier by Talent (1963), indicate some affinity with Arctic and western North American faunas, although these latter two taxa are distinct enough to receive separate generic names.

The stratigraphic range of the known species, named and unnamed, discussed above, appears to fall within the latest Siegenian and the Emsian (Fig. 1). The proposed phylogeny suggests that *Muriferella* gave rise to *Vallomyonia* some time in the Eifelian, but as yet no early Eifelian occurrence of either genus is known, so their full ranges are still to be determined. *Muriferella* itself seems so close to Gedinnian *Salopina* that occurrences may be discovered later to extend the range of the genus down even into the Gedinnian.

#### ***Muriferella masurskyi* n. sp.**

(Pl. 9, figs. 1-14)

1965 *Mystrophora* cf. *M. areola* Merriam in Gilluly & Masursky, p. 32, not Quenstedt.

**DIAGNOSIS:** Relatively large *Muriferella* with low dorsal interarea and thick median septum extending to the anterior margin.

**EXTERIOR:** The species attains a relatively large size with specimens having a maximum width between 7 and 11 millimetres across fairly common. The valves are unequally biconvex in lateral profile with depth of the pedicle valve exceeding that of the brachial valve by two or three times. The brachial valve convexity is poorly developed because of the presence of a well marked angular median sulcus that is relatively narrow posteriorly, but broadens in width, though not much in depth, toward the anterior margin. The pedicle valve is smoothly rounded to very faintly subcarinate in cross-sectional outline so that the anterior commissure approximately parallels the hinge line or may be slightly reentrant medially. The hinge line is short and straight and slightly exceeds half the maximum width to as much as about two-thirds the maximum width. The ventral interarea is flat and triangular, but may be slightly curved at the beak. It is, in general, relatively steeply apsaeline and is cleft medially by an open triangular delthyrium encompassing an angle of about 30 degrees. The ventral beak is short and the umbo not prominent. The dorsal interarea is low, only faintly triangular, flat, and anaeline, approaching but not reaching the orthocline position in some larger specimens. The maximum width is generally attained near midlength of the pedicle valves across the decidedly transverse subquadrate or suboval outline.

The exterior is covered with numerous fine rounded costellae that increase in number anteriorly by bifurcation and by implantation.

**INTERIOR OF PEDICLE VALVE:** The hinge teeth are stubby triangular projections diverging a little more widely laterally than the inner edges of the delthyrium and projecting dorsally in the plane of the ventral interarea. They are joined basally by short, commonly thin, plate-like dental lamellae that bow laterally in some specimens, descend directly in subparallel fashion in others, and diverge very slightly toward the base of the valve in still others. They enclose a short triangular muscle field with the adductor and diductor scars not separately differentiated. The anterior margin of the muscle field is commonly marked by a low transverse ridge, or the anterior may blend almost imperceptibly with the interior of the valve. The valve margins are crenulated peripherally by flat crenulations separated by narrow groove-like interspaces.

**INTERIOR OF BRACHIAL VALVE:** The brachiphores are triangular and prism-like, directed anteroventrally and diverging in that direction. Basally they thin and become plate-like and join the floor of the valve. In specimens where the cardinalia are relatively thin the plate-like, basal portions of the brachiphores diverge anteriorly at about the same angle as the ventral edges and descend from them in a subparallel fashion towards the base of the valve. The sockets are cylindroidal grooves defined lateral to the brachiphores and basally by fuleral plates. In some specimens the area around the cardinalia becomes thickened with shell material so that the plate-like bases of the brachiphores and the fuleral plates become welded together. The cardinal process has a short, bilobate shaft lying at a low angle on the thickened notothyrial platform with its myophore facing posteriorly. The anterior base of the cardinal process shaft, or in some cases the thickened notothyrial platform, is continuous anteriorly with a stout low median septum that extends to the anterior margin. It increases only slightly in height anteriorly and is not high and triangular, but may reach to a height three or four times its thickness. The bases of the brachiphores continue anteriorly as long, low, subparallel, adductor muscle bounding ridges that commonly extend well past mid-length. Some variation in the development of muscle bounding ridges exists so that the overall pattern may be elongate-oval or there may be a pair of indentations at the point of joining between the

posterior and anterior pairs. In a few specimens, particularly the larger ones, the adductor bounding ridges become disjunct from the brachioophore bases which then lie slightly within them, as in *Salopina*. The anterior margins are crenulate in a similar fashion to those of the pedicle valve, but a few specimens show the development of peripheral radial septa developed medially, adjoining the median septum.

COMPARISON: *Muriferella masurskyi* differs from *M. punctata* in being larger, commonly about twice the width, and in having thicker shell substance, the latter distinction being clear-cut even when comparing specimens the same size as those available of *M. punctata*. In addition, the dorsal interarea of *M. punctata* is steeper, higher, and decidedly more prominent. The dorsal median septum of *M. masurskyi* is thicker than in *M. punctata* and reaches to the anterior margin, the latter condition being uncommon in the Australian species.

OCCURRENCE: *Muriferella masurskyi* is present at the following two USNM localities in the *Eurekaspirifer pinyonensis* zone of Nevada.

10752—Wenban Limestone, east slope of Cortez Range, elev. 7950', 1000' N., 700' W. of SE. cor. of sec. 4, T. 26N., R. 48E., Cortez quad., Eureka Co., Nevada. Collectors: A. J. Boucot and E. F. Lawrence, 1963; A. J. Boucot, H. K. Erben, and K. L. Gauri, 1965.

10754—Wenban Limestone, west slope of Cortez Range, elev. 6875', 800' N., 2900' E. of SW. cor. of sec. 21, T. 26N., R. 48E., Cortez quad., Eureka Co., Nevada. Collectors: A. J. Boucot and H. Masursky, 1963.

FIGURED SPECIMENS: USNM 141442-141449. The holotype is USNM 141442 illustrated in figs. 1-5 of Pl. 9.

### ***Muriferella punctata* (Talent 1963)**

(Pl. 10, figs. 1-13)

1963 *Phragmophora punctata* Talent, p. 60, Pl. 28, figs. 1-37; Fig. 21.

DISCUSSION: In addition to the remarks originally made by Talent when first describing this species (1963, p. 60, 61) several other points may be brought out here. The external radial ornament is found to consist of hollow costellae (Pl. 10, fig. 11). The interarea on the brachial valve is relatively well developed, flat, triangular, and anacline, and it commonly extends ventrally covering the posterior ends of short sockets whose bases are defined by stout but short fulcral plates. The brachioophores themselves are relatively sharply triangular and are supported by thin brachioophore supporting plates that continue smoothly anteriorly as ridges laterally bounding the area of the adductor impressions. The notothyrial platform mentioned by Talent appears to be formed by a pair of ancillary struts (Williams & Wright 1963, p. 9). The base of the cardinal process continues anteriorly without interruption into the median septum which is thin and low through its entire length. In some specimens the median septum becomes somewhat elevated anteriorly, but does not become high and triangular as in some small dalmanellids such as *Prokopia*, *Mone-lasmina*, or as in the mystrophorids. The median septum commonly terminates somewhat short of the anterior margin of the valve, but may extend a little further anteriorly than its anterior-most point of connection with the floor of the valve.

FIGURED SPECIMENS: Geol. Surv. Vic. numbers 55962F, 56008, 56007B, 56007C, 56045A. USNM numbers 140448-140450.

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of *Muriferella masurskyi* from the Cortez Range, central Nevada, to Drs D. J. McLaren and J. W. Kerr of the Geological Survey of Canada for the loan of unnamed specimens of *Muriferella* from Bathurst Island, and to Dr A. C. Lenz of the University of Western Ontario for the loan of unnamed specimens of *Muriferella* from the *Monograptus yukonensis* zone in Yukon Territory. We are further indebted to Mr Kazys Kemežys for discussion of related brachiopods during an early stage of the preparation of the present paper, and to Mr Norman Savage for photographs and information about septate resserellids and the new Lower Devonian septate shell from New South Wales related to *Mystrophora* and *Kayserella*. The writers would also like to extend their thanks to Drs Walmsley, Boucot, and Harper for access to plates prepared by them dealing with the species of *Salopina*. Johnson's work at Pasadena was supported by a grant from the National Science Foundation to the California Institute of Technology supporting work on Silurian and Lower Devonian brachiopods, Grant No. 54034.

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### Explanation of Plates

#### PLATE 9

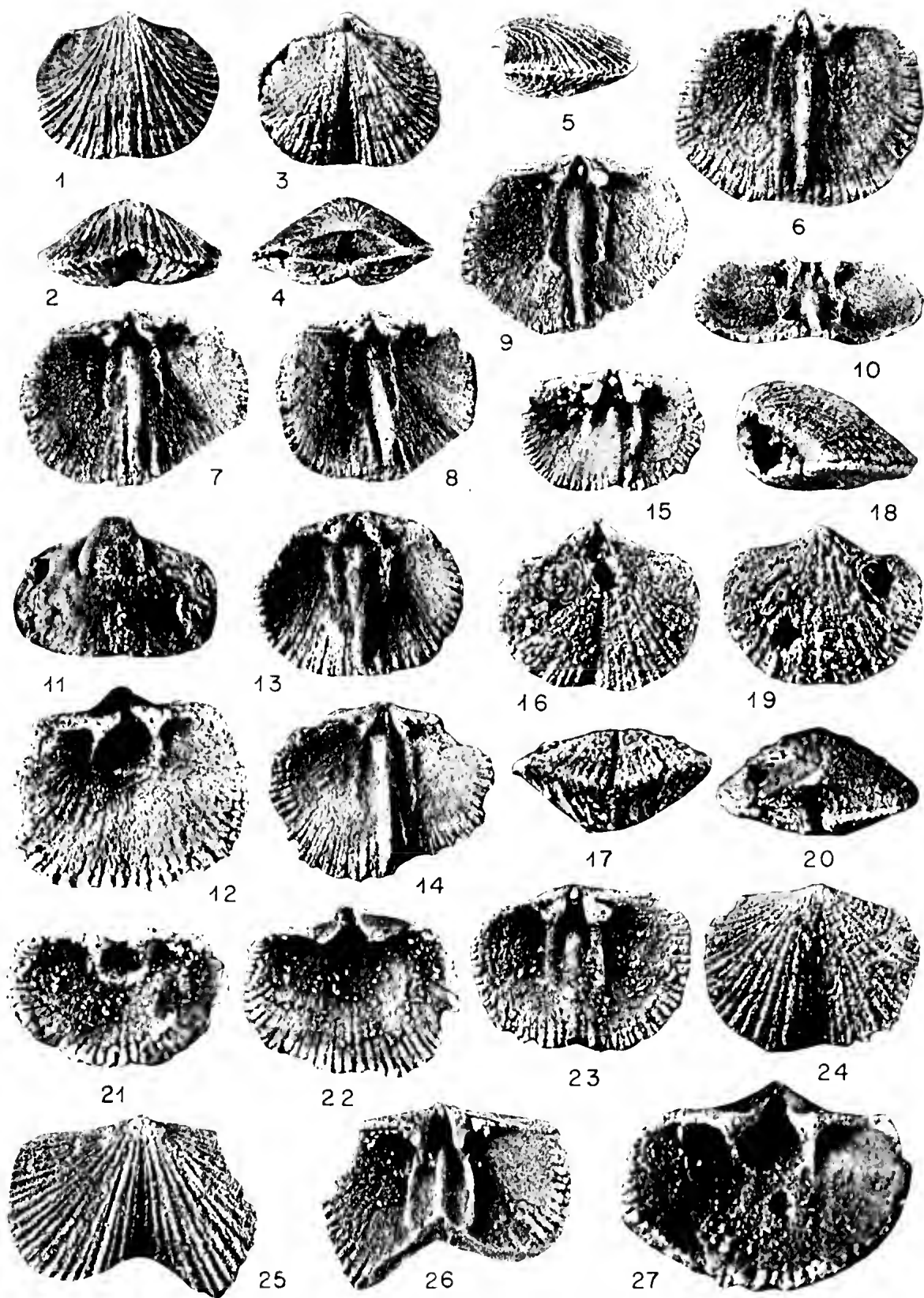
FIGS. 1-14—*Muriferella masurskyi* n. sp. *Eurekaspirifer pinyonensis* zone, Cortez Range, central Nevada, figs. 1-11, USNM loc. 10752, fig. 12, USNM loc. 10754. 1-5, Ventral, anterior, dorsal, posterior, and side views  $\times 4$ , holotype, USNM 141442. 6, Interior of brachial valve  $\times 6$ , USNM 141443. 7, 8, Plan and oblique views of interior of brachial valve  $\times 6$ , USNM 141444. Note pair of peripheral septa disposed anteromedially. 9, 10, Plan and anterior views of interior of brachial valve  $\times 6$ , USNM 141445. Note disposition of the brachiphore bases and of the presence of cavities lateral to them beneath the fuleral plates. 11, rubber mould of

interior of pedicle valve  $\times 5$ , impression of USNM 141447. 12, Interior of pedicle valve  $\times 7$ , USNM 141446. 13, Interior of brachial valve  $\times 6$ , USNM 141449. 14, Interior of brachial valve  $\times 6$ , USNM 141448.

FIGS. 15-27—*Salopina* cf. *crassiformis* (Kozłowski, 1929). Upper Roberts Mountains Formation, beds of Gedinnian age, between Birch and Willow Creeks, northern Roberts Mountains, USNM loc. 12856. 15, Interior of brachial valve  $\times 10$ , USNM 155421. 16-20, Dorsal, anterior, side, ventral, and posterior views  $\times 10$ , USNM 155422. 21, 22, Anterior and plan views of interior of pedicle valve  $\times 10$ , USNM 155423. 23, 24, Interior and exterior views of brachial valve  $\times 10$ , USNM 155424. 25, 26, Exterior and interior views of brachial valve  $\times 10$ , USNM 155425. 27, Interior of pedicle valve  $\times 10$ , USNM 155426.

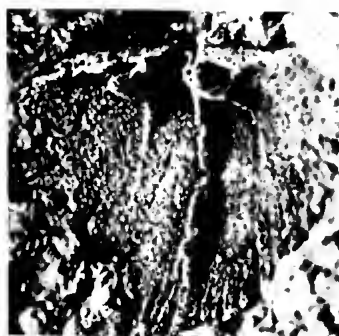
#### PLATE 10

FIGS. 1-13—*Muriferella punctata* (Talent, 1963). Kilgower Member, Tabberabbera Formation, Victoria, Australia. Locality 35 of Talent (1963). 1-4, Three different aspects of dorsal interior, rubber replica  $\times 10$  and internal mould of brachial valve  $\times 7$ , Geol. Surv. Vic. 55962F. 5, Internal mould of pedicle valve  $\times 7$ , Geol. Surv. Vic. 56008. Note long anteriorly convergent vascular tracks. 6, Posterior view of internal mould of brachial valve  $\times 10$ , USNM 140448. Note the well developed slots which accommodated the fulcral plates. 7, Internal mould of brachial valve  $\times 7$ , Geol. Surv. Vic. 56007B. 8-10, Two aspects of dorsal interior, rubber replica  $\times 10$  and internal mould of brachial valve  $\times 7$ , Geol. Surv. Victoria 56007C. Note that the median septum is free anteriorly. 11, Mould of exterior  $\times 10$ , USNM 140449. Note the small rods of matrix in the grooves corresponding to the costellae owing to their hollow structure. 12, Mould of interior of pedicle valve  $\times 10$ , USNM 140450. 13, Internal mould of pedicle valve  $\times 10$ , Geol. Surv. Vic. 56045A. Note radial grooves at the venter anteriorly and the very numerous pip-like moulds of the endopunctae.





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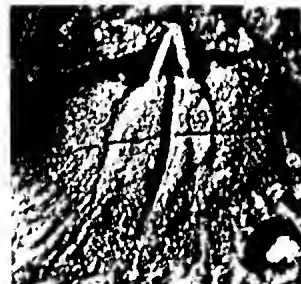
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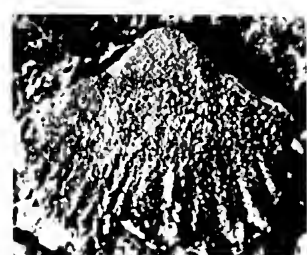
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## UPPER DEVONIAN SEDIMENTS OF THE CANN, COMBIENBAR AND BEMM RIVERS AREA, EASTERN VICTORIA

By D. SPENCER-JONES  
Geological Survey of Victoria

### Abstract

Three areas of Upper Devonian sediments outcropping in the valleys of the Upper Cann, Combienbar and Bemm Rivers of Eastern Victoria, have recently been mapped in some detail. The sediments are preserved in small troughs downfaulted into the Lower Palaeozoic basement rocks and consist of sandstones, conglomerates, red sandstones and red siltstones with the 'red bed'-type sediment predominating in the upper part of the succession. Certain horizons contain poorly preserved plant fossils and fragmental fish remains, but most of the succession is unfossiliferous. The sandstones within the sequence are quartzose and lithic sandstones with the latter containing rock fragments of mainly local provenance.

### Introduction

Reconnaissance mapping in Eastern Victoria during recent years has yielded information on the distribution and nature of Upper Devonian sediments outcropping in the valleys of the Upper Cann, Combienbar and Bemm Rivers. Prior to the publication of the 1:1,000,000 geological map of Victoria by the Mines Department in 1963, only two areas of these rocks were shown on maps, one in the Bemm River valley and the other in the Upper Cann River valley. The recent mapping established that three discrete areas of outcrop occur in small inliers downfaulted into the Lower Palaeozoic basement rocks. (Fig. 1a.)

The Upper Devonian rocks outcrop mainly in negative relief areas and contrast with other areas of Upper Devonian-Lower Carboniferous rocks in Gippsland where the massive outcrops constitute rugged highland country e.g. the Avon River Group of Northern Gippsland and the Genoa River Beds of eastern Victoria. The absence of large thicknesses of massive and resistant quartzose sandstones from the Upper Cann, Combienbar and Bemm River successions is one factor contributing to the lack of dominant land forms.

The rivers, particularly the Cann and Combienbar, have eroded their courses along the axes of the fault troughs in which the comparatively soft Upper Devonian sediments have been preserved, and the Bemm River southwest of Club Terrace has carved a valley into the softer 'red bed'-type sediments of the succession.

Previous published work on this district is confined to brief references to alluvial and reef gold mining (Whitelaw 1898, Stirling 1898, Murray 1898) and notes on the physiography of the County of Croajingolong by Stirling (1889). Stirling recorded sandstones and conglomerates of probable Devonian age on the divide between the Cann and Bemm Rivers and steeply dipping quartzose sandstones and red sandstones at Buldah in the Upper Cann River valley. Whitelaw (1898) noted Devonian sandstone, shale and conglomerates unconformably overlying slates in a tributary of the Cann River northeast of Buldah. In more recent times Thomas (1949) referred to reddish shales and sandstones in cuttings on the Princes Highway near the Bemm River bridge.

A thin residual of weathered basalt caps a spur bearing northwest from the junction of the Goolengook and Bemm Rivers. This outcrop was mentioned by Whitelaw (p. 65) with reference to alluvial mining in the Bemm River valley. Underlying the basalt there is a thin deposit of sand and gravel containing boulders and cobbles of reef quartz, slate, granite and metamorphic rocks (Whitelaw *op. cit.*). The rock is an olivine labradorite basalt consisting of phenocrysts of olivine and labradorite set in a groundmass of labradorite laths, granular augite, iron ore mineral and yellow brown coloured glass. The basalt probably belongs to the Older Volcanic Suite of Lower Tertiary age.

Quartz gravels are found capping spurs in the southern part of the Bemm River area between the tributary streams Goolengook River, Crab Hole Creek and Boulder Creek. These gravels occur at approximately the same level as those underlying the basalt lava. Other gravel deposits are found down in the Bemm River valley on the lower slopes southwest of Club Terrace.

The Upper Devonian sequence has been tentatively divided into three units. Units 1 and 3 are distinguished by the relative abundance of 'red bed'-type sediments and Unit 2 is recognized only in the Combienbar succession. The units will be described in more detail later in the text. The boundaries between the units as shown in Figs. 1b and 2 are not sharply defined in the field.

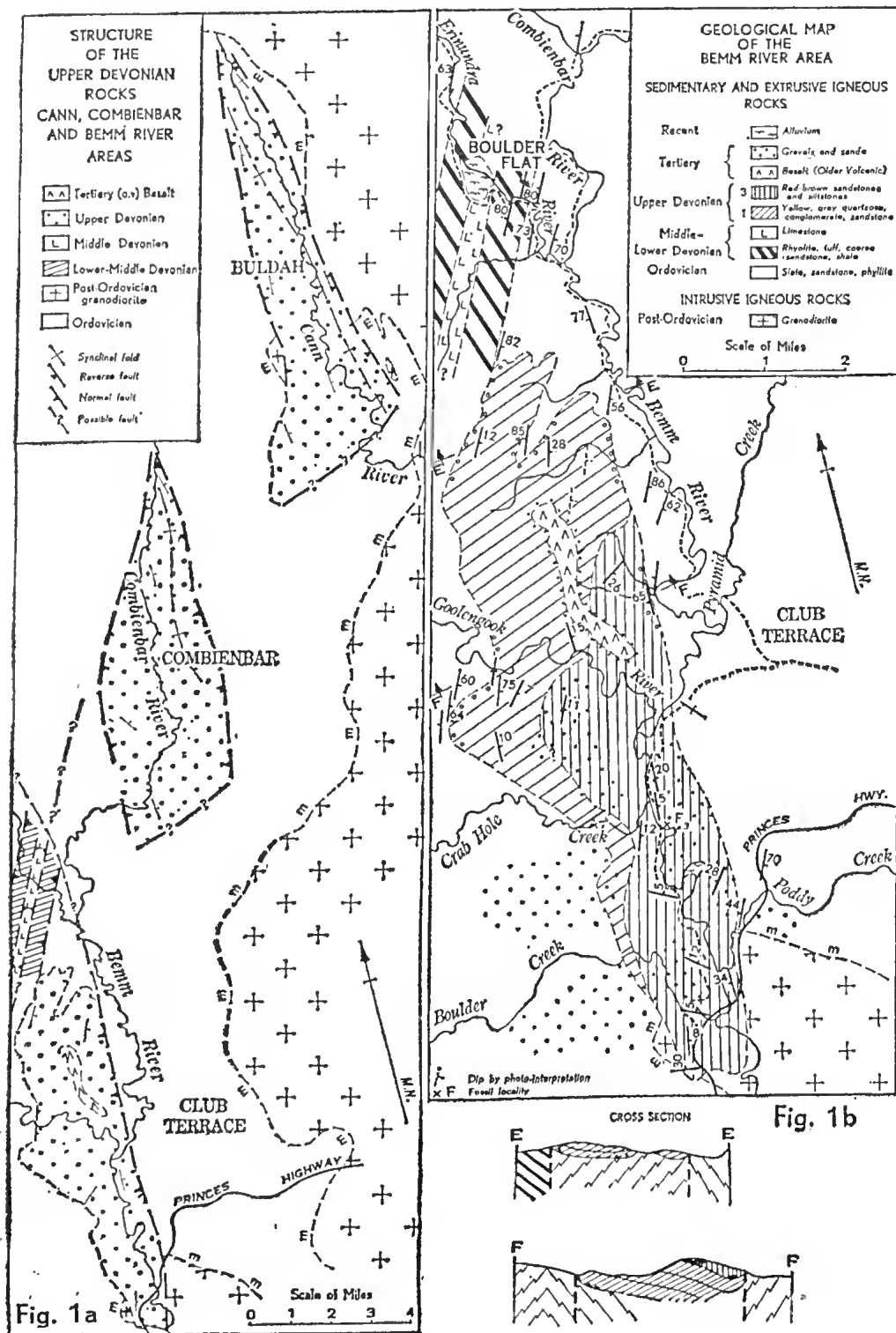
The sedimentary rocks rest unconformably on tightly folded Lower Palaeozoic sedimentary rocks and intrusive granitic rocks. In road cuttings on the Princes Highway near the Bemm River bridge, an unconformable contact is exposed between red sandstones, siltstones and weathered granodiorite. This contact between sediments, which are believed to be high in the Bemm River sequence, and the granodiorite, suggests that the pre-Upper Devonian surface was quite irregular. Lenticular bedding however could complicate the stratigraphic interpretation.

#### The basement rocks

The basement rocks include slates, sandstones, mudstones, phyllites, mica schists and hornfels, which are lithologically comparable with the rocks forming highland country in the County of Croajingolong. These rocks are tightly folded and cleaved, varying in strike from WNW to ENE. No fossils were found in these rocks during the recent mapping but lithologically they are comparable with rocks in which Carne (1897) and Thomas (1949) found graptolites of Upper Ordovician age.

East and south of the areas of Upper Devonian outcrop, the basement sedimentary rocks are intruded by the granitic rocks which are continuous with the Bega Granite complex of southeast New South Wales. Hall (1959, 1960) has described the Bega Granite as a composite intrusion varying in composition from a muscovite granite to a hornblende biotite granite. Samples collected from Victoria vary from pinkish grey to dark grey in colour and are fine to coarse grained. In thin section the rock has the composition of a hornblende granodiorite. The granodiorite is usually massive, but strong foliation can be observed in some areas. The metamorphic aureole along the western edge of the mass is narrow, considering the size of the granitic mass, and where exposed in a gorge in the Cann River valley downstream from the Look Up Creek junction, the contact is steeply dipping to the west.

At Boulder Flat (Fig. 1b) on the Errinundra River approximately 1½ miles upstream from the junction with the Combienbar River, a narrow belt of Lower Middle Devonian rocks outcrop. The rocks, consisting of acid lavas interbedded with tuffs, agglomerates, coarse sandstones, mudstones, fossiliferous shales and limestones, which are strongly sheared and metamorphosed (Talent 1965), have been downfaulted into the basement rocks. Thomas (1949) mapped a section





along the Errinundra road and noted a high angle strike fault along the eastern edge between Upper Ordovician slates and tuffaceous sediments. The belt is only 1½ miles wide with the limestone outcropping along the middle of the structure and lavas and sediments to the east and west. Teichert (1946) recorded fossils of Middle Devonian age from the limestone and suggested that the formation was equivalent to the Buehan Limestone, and Bain (1949) examined the associated rhyolite lavas and tuffs and described them as equivalents of the Snowy River Volcanics. Along the New South Wales coast near Eden, volcanics of similar composition outcrop and Hall (1949) has suggested that these rocks which underlie Upper Devonian sediments and volcanics could be Lower to Middle Devonian in age.

The belt of rocks at Boulder Flat has been mapped as far south as the north-west edge of the Upper Devonian outcrops, and north of the Errinundra River, but does not outcrop on the spur between Bungywaar Creek and the Errinundra River valley. It is possible that the structure has been truncated by faulting as depicted in Fig. 1a, but more detailed mapping will be necessary to establish the true relationship.

### The Upper Devonian rocks

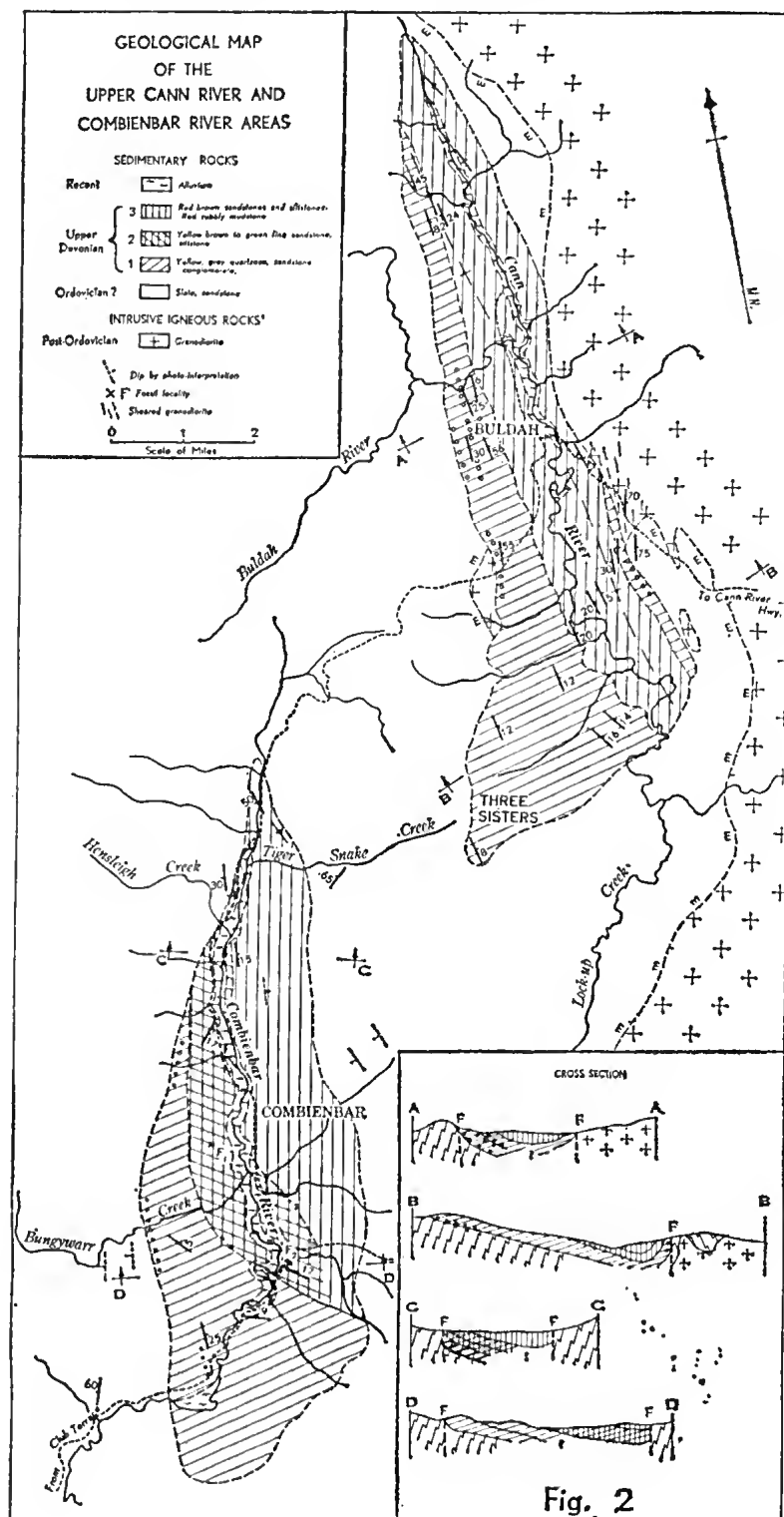
These rocks consist of relatively soft, gently dipping sediments varying from cobble conglomerates to siltstones and mudstones. Rock types include yellow to grey quartzose sandstones, polymict and oligomict conglomerates, pebbly quartzose sandstones, greenish to brownish grey medium grained sandstones and purplish to red sandstones, siltstones and mudstones. The strata is predominantly easterly-dipping except near the eastern marginal faults where drag has produced steep westerly dips and overturning. The easterly dip results in the oldest sediments of the sequence outcropping along the western edge of the fault troughs. This interpretation is used in the cross-sections A-F (Figs. 1b & 2). An assumption made in the drawing of these sections is that the beds are not lenticular. Because of the absence of good continuous outcrop the lateral development of individual beds could not be studied, but in the example of Unit 2 in the Combienbar area this group of beds appeared to be persistent in lateral extent. A total thickness of between 2,000 and 3,000 feet of sediment may be present if the beds are continuous as shown in the cross-sections.

A tentative subdivision of the formation into three units has been proposed until a better correlation can be made.

#### UNIT 1

This unit forms the lower beds of the succession in each area and includes mainly yellow brown to grey quartzose sandstones, yellow to red pebbly sandstones and conglomerates with subordinate grey, red, yellow medium grained sandstones and siltstones. Conglomerates and pebbly sandstones are consistently found along the western edge of the three areas, but they are also found higher in the sequence. These conglomerates are probably lenticular within quartzose sandstone groups of beds and cross-bedding is a common feature. The conglomerates near the western edge of the fault troughs are polymict with well rounded reef quartz pebbles and cobbles, and sub-rounded to angular pebbles and cobbles of quartzite, sandstone and slate make up the other rock types. Granitic rocks were not observed as pebbles or cobbles, even though a large tract of the country east of the area is composed of granitic rocks. In the oligomict conglomerates and pebbly sandstones the rock types are usually reef quartz and quartzite.





## UNIT 2

This unit occurs only within the Combienbar succession and consists of approximately 500 ft of green to brown medium grained micaceous sandstones with some red sandstones and siltstones. The sediments are slabby to well bedded with some laminated strata. The lighter coloured beds contain fragmental fossil plant material and two collections were made from localities F1 and F2 (see Fig. 2). At locality F1 a large stem east was found and several samples contained small indeterminate fish plates. If large enough excavations are made at locality F1, some worthwhile specimens may be obtained.

## UNIT 3

This part of the succession consists mainly of red bed-type sediments, purplish red to brownish red medium grained sandstones, siltstones and 'rubbly red' mudstones with characteristic spherical and crumbly mode of weathering and lack of obvious bedding. Occasional pebble beds occur in this unit as well as laminated pink, grey, yellow and green fine grained sandstones and siltstones. Some of the thin red and green siltstone beds (locality F3) contain fragmental plant fossil remains, but most of the material is indeterminate.

The Upper Cann, Combienbar and Bemm Rivers have eroded relatively wide valleys in the sediments of this unit. Where the streams have carved into the Lower Palaeozoic rocks, the valleys tend to be narrow and steep-sided. Alluvial flats have been formed by the Upper Cann and Combienbar Rivers where they flow through the red beds. These alluvial flats were heavily timbered in their virgin state (Stirling 1889, p. 86) although the foothills were sparsely timbered and well grassed.

**Age evidence and correlation**

The stratigraphic evidence suggests that these sediments are younger than the Bega Granite (epi-Middle Devonian according to Hall (1959)) and the Lower-Middle Devonian volcanic and sedimentary rocks which they partly overlie south of Boulder Flat. Lithologically the sediments resemble rocks between Platte and Bombala in New South Wales described by McRoberts (1948) and the Genoa River Beds in the Upper Genoa River valley. Carne (1897) collected plant fossils from the Genoa River Beds and Dun (1897) described them as typical of the Upper Devonian. Hall (1959) suggested that the Genoa River Beds are the non-marine lateral equivalents of the Merrimbula Formation of the Eden-Pambula district of south-east New South Wales, because of the presence of similar plant fossils in the two formations. The Merrimbula Formation consists of conglomerates, arkose, shale, purple brown sandstones and quartzite, and marine fossils and plant fossils have been found in the formation (Brown 1931). Faunas from marine beds within the Merrimbula Formation collected in the vicinity of Eden by J. Steiner of the Australian National University include *Cyrtospirifer australis* and *Cyphopterorhynchus* inter alia, on the one hand re-emphasizing the 'Lambian' affinities of the fauna and its Upper Devonian age, and indicating that the fauna is most probably late Frasnian (J. A. Talent, pers. comm.). The Merrimbula Formation conformably overlies and overlaps the Loehel Formation, which consists of interbedded conglomerates, sandstones, shales and volcanic rocks (Hall 1959). The Upper Cann, Combienbar and Bemm River sequences do not include any volcanic rocks, although detrital fragments of possible igneous origin are found in the sandstones. These are not regarded on present evidence as being marine in origin, but there is no evidence against them being regarded as a lateral equivalent of the Merrimbula Formation, a correlation which Hall has suggested for the Genoa River Beds.

J. G. Douglas of the Geological Survey of Victoria kindly examined plant fossils collected from locality F1. He noted that most of the specimens contained plant debris, small branches and fern-like foliage, but one large stem cast of the Order *Lepidodendrales* was found in the collection. From the rather poor material, Mr Douglas deduced that the sediments were not older than Upper Devonian.

### Composition of the sandstones

The sediments included in these Upper Devonian successions vary in grain size from cobble conglomerates to red mudstones. To obtain some information relevant to the source rock of the sediments, thin sections were made of specimens of sandstone from different localities. Micrometric analyses were made and the results plotted as a QFR diagram (Fig. 3), where Q is detrital quartz content, F—Felspar and R—rock fragments, calculated on a matrix free basis. The composition varies from quartzose sandstone to lithic sandstone independent of the unit from which the samples were collected.

*Average micrometric analyses*

Unit	No. of Samples	Quartz	Felspar	Rock Frags.	Mica	Iron oxide	Matrix
1	6	65.6	2.8	19.0	0.2	0.7	11.6
2	2	64.4	1.4	12.8	0.9	0.3	20.1
3	14	60.8	1.5	16.0	0.8	1.8	19.1

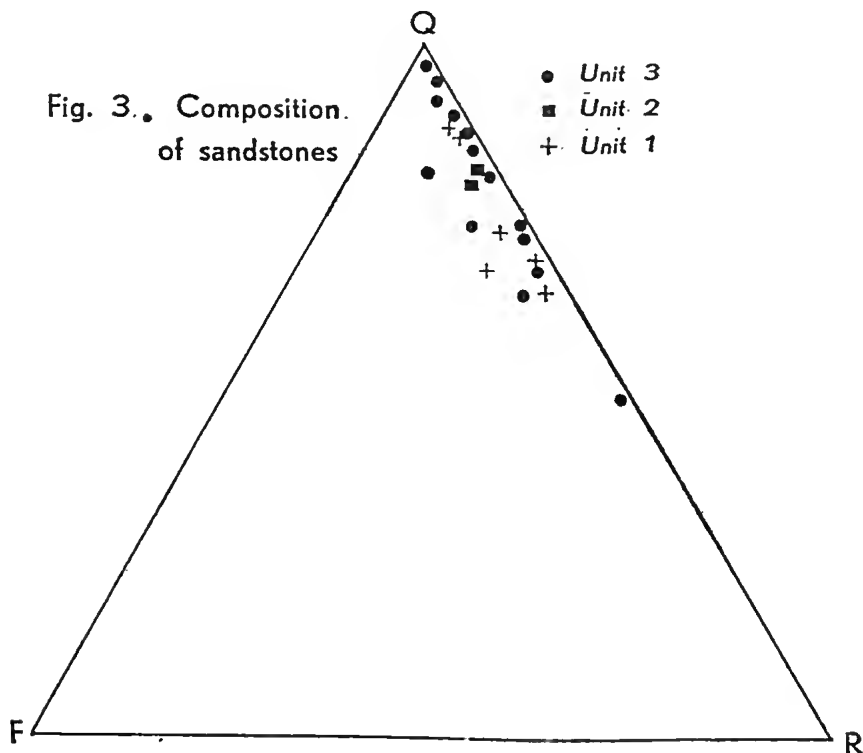
The rock types represented as detrital fragments are predominantly of local provenance except for rare dyke or lava rocks with trachytic texture. Common lithologies were Lower Palaeozoic sandstone, quartzite, reef quartz, slate, black slate, mica schist, quartz schist and contemporaneous sediments such as red siltstone and mudstone. Most of these rock types outcrop in the immediate area. Although a considerable proportion of the country east of the areas consists of granitic rocks which are pre-Upper Devonian, it is significant that felspar is not an important constituent in the sandstone composition. Specimens from the Upper Cann River area contained up to 7.9 per cent, but others from the southern part of the Bemm River area where the sediments unconformably overlie decomposed granodiorite, did not contain a high percentage of felspar.

The absence of granitic rock types from the conglomerates and the low felspar content of the sandstones contrasts markedly with the Genoa River Beds which have a basal arkosic conglomerate (Hall 1959). Similarly both the Merrimbula Formation and the Lochiel Formation along the south-east coast of N.S.W. contain arkose and arkosic conglomerates. The comparatively high percentage of basement rock fragments, mainly Upper Ordovician sediments and metamorphics, within the lithic sandstones of the successions may suggest that the source area for the sediments was to the west, where with the exception of the Mt Ellery granodiorite the rocks are of sedimentary or metamorphic type.

### Structure

The small inliers of comparatively soft Upper Devonian sediments undoubtedly owe their preservation to down-faulting into the basement rocks. The sediments probably were originally part of more extensive deposits passing laterally into marine equivalents to the east.

The strata are generally easterly dipping with strike direction varying from north-west to north-east in the Combienbar and Bemm River areas (Figs. 1b and 2). Near the trough margins the strike directions are influenced by the drag effects of the boundary fault. Drag along the eastern boundary faults has resulted in steep westerly-dipping and overturned strata. The resulting structure within fault troughs is an asymmetrical syncline as shown in the cross-sections A to F (Figs. 1b and 2). Along the western edge of the structures faulting has also steepened easterly dips and produced overturning. The overturning of the beds can be observed where roads cut across the structure, as for example on the Buldah Gap road (Fig. 2). At this locality the intensity of the faulting and shearing on the eastern edge of the Upper Cann River section is indicated by a wide zone of mylonised granodiorite. The degree of overturning produced by the boundary faults, particularly in the Upper Cann and Combienbar areas, suggests that the faults may be high angle reverse faults in part. In both these areas the faults converge to the north, pinching-out the Upper Devonian sediments. In the upper part of the Cann River section near the headwaters of the stream, the only Upper Devonian sediments visible are



in the bed of the stream while the sides of the narrow valley are composed of Ordovician rocks. The faulted contacts are blanketed by scree deposits. The influence of the boundary fault along the western edge of the Upper Cann structure appears to decrease to the south or perhaps changes in direction. In the vicinity of the Three Sisters, which consist of questa-type peaks of coarse pebbly sandstone, the contact

appears to be an unconformable rather than a faulted relationship (Fig. 2). In the Bemm River area the eastern boundary fault is exposed in tributary streams of the Bemm River west of Club Terrace. The extrapolation of this fault to the north-west to terminate the narrow belt of Lower-Middle Devonian rocks north of Boulder Flat (Fig. 1a) is conjectural. The structural relationship between the Upper Devonian rocks and the basement rocks along the western edge of the Bemm River succession is not clear. In the bed of the Goolengook River the Ordovician rocks are in faulted contact with steep easterly-dipping Upper Devonian pebbly sandstones, but on the spur to the south between the Goolengook River valley and the Crab Hole Creek valley, the contact appears to be a gentle easterly-dipping unconformity. Outcrops on the new alignment of the Princes Highway suggest an unconformable rather than a faulted contact on the western margin. However an irregular pre-Upper Devonian surface and steep topography possibly complicate the picture.

The prevailing easterly dips of the Upper Devonian rocks could indicate that the narrow belt of Lower to Middle Devonian rocks at Boulder Flat is part of a major structure which has controlled the western limits of the Upper Devonian outcrops. The three small structural troughs are arranged 'en echelon', appearing as lozenge-shaped areas which may be the expression of a regional shear pattern; however shear zones in the basement rocks would have to be mapped and studied in detail to obtain an idea of a regional structure pattern.

### Acknowledgements

The author is grateful to Dr D. E. Thomas, Director of Geological Survey, for permission to submit this paper for publication, and to Mr R. G. Williams for his help and companionship in the field. Mr J. G. Douglas kindly examined the fossil plants, and Dr J. A. Talent supplied the information on the recent determination of fossils from the Merrimbla Formation.

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## RECENT OSTRACODA FROM PORT PHILLIP BAY, VICTORIA

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**Abstract**

In a taxonomic study of the Ostracoda from two localities in northern Port Phillip Bay, Victoria, 32 new species are proposed. These are: *Cytherelloidea keiji*, *Paracypris bradyi*, *Australoecia victoriensis*, *Loxocythere hornibrooki*, *Australocytheridea vandenboldi*, *Copypus rara*, *Parakrithella australis*, *Cytherura taylori*, *Semicytherura tenuireticulata*, *S. angusta*, *S. paenunuda*, *Hemicytherura scaliolmensis*, *Microcytherura australis*, *M. gawemuelleri*, *M. triebeli*, *Callistocythere puri*, *C. hartmanni*, *C. insolita*, '*Hemicytheridea*' *portjacksonensis*, *Loxoconcha trita*, *L. gilli*, *Loxoconchella pulchra*, *Paradoxostoma romei*, *P. commune*, *P. trapezoideum*, *Cytherois dissimilis*, *C. bonaducei*, *Paracytherois portphillipensis*, *Microcythere macphersoni*, *Cletocythereis curta*, *Xestoleberis briggsi*, and *Doratocythere foveata*. In addition, the genera *Australoecia* (type species *Australoecia victoriensis*), *Australocytheridea* (type species *Australocythereidea vandenboldi*), *Ponticocythereis* (type species *Ponticocythereis militaris* (Brady), 1866) and *Doratocythere* (type species *Doratocythere foveata*) are described as new. The study closes with a brief comment on the distinctive features of each faunule.

**Introduction**

During October 1964, while accompanying Miss H. Macpherson, then Curator of Molluscs at the National Museum of Victoria (now Mrs I. Black), on a field excursion the writer sampled a tide pool at Seaholme. Later in the month, accompanying Miss Macpherson and Dr A. W. B. Powell of the Auckland Museum, he collected from the swash mark at Ricketts Point, near Scaford (Fig. 1). Each collection yielded a rich faunule of ostracode species. Ostracode taxonomy has long been neglected in Australia but it is hoped that this paper, in the centenary year of the first major attempt to describe Australian marine species (Brady 1866) will stimulate the interest of local neontologists and palaeontologists in these fascinating and informative microcrustaceans.

In the descriptions below the conventions RV (right valve) and LV (left valve) are used throughout (Moore, ed. 1961).

Holotypes and paratypes are lodged at the National Museum of Victoria under registered numbers J35-112. In addition, topotypes of the commoner species have been forwarded to the British Museum (Natural History), the United States National Museum, the Henry V. Howe Museum, the Senckenberg Museum and Stazione Zoologica.

As far as is known at present the entire faunule is of Recent age.

**Systematic Descriptions**

Subclass OSTRACODA Latreille, 1806

Order PODOCOPIDA Müller, 1894

Suborder PLATYCOPINA Sars, 1866

Family CYTHERELLIDAE Sars, 1866

Genus *Cytherelloidea* Alexander 1929

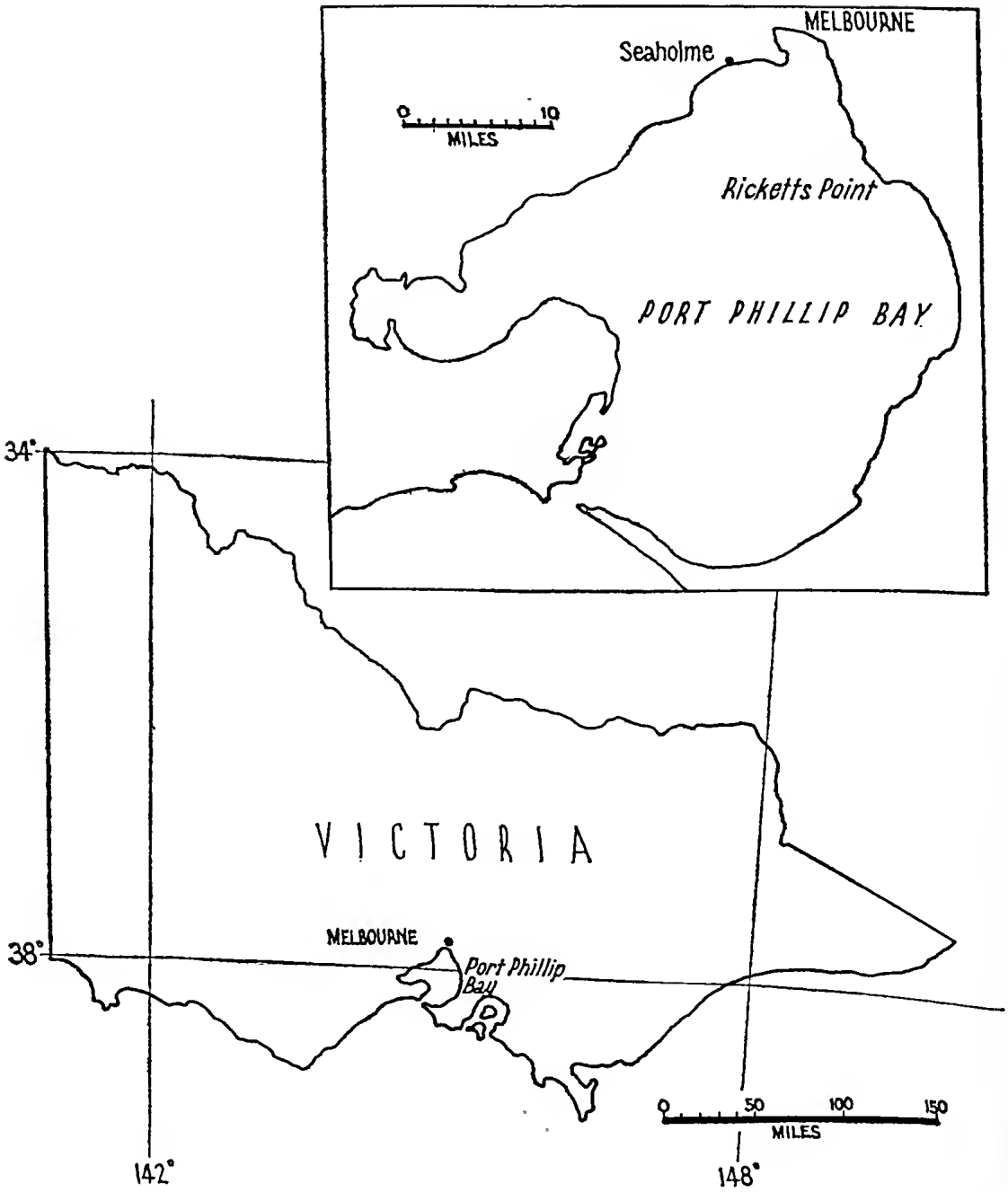


FIG. 1—Locality map of sampling points, Port Phillip Bay, Victoria.



***Cytherelloidea keiji* sp. nov.**

(Pl. 11, fig. 1; Fig. 3p)

(?) *Cytherelloidea* sp. van den Bold, 1963, p. 76, Pl. 1, fig. 8.

DERIVATION OF NAME: For the micropalaontologist, A. J. Keij, who recently (1964) described several species of *Cytherelloidea* from Neogene to Recent sediments of north-western Borneo.

MATERIAL: Seaholme, 5 individuals; Ricketts Point, 11 individuals.

DIAGNOSIS: Shell medium-large; subrectangular in lateral view; external surface pitted, further ornamented by an antero-marginal ridge and two longitudinal ridges which begin at a transverse posteromarginal ridge; RV larger than LV, overlapping it strongly in the dorsal region; dorsal margin straight, sloping gently backwards, sinuated antero-dorsally, anterior margin broadly rounded, denticulate; ventral margin sinuated medially, posterior margin subtruncate, rounded above and below, height subequal throughout the length. Internally: lamellae narrow, fused with the shell; radial pore canals absent, but several straight and widely spaced pseudoradial pore canals occur; normal pore canals few, simple, open; muscle scars arranged in the usual biserial cluster, situated sub-centrally on an internal node; hingement modified overlap, LV with a broad based, triangular, toothlike structure at  $5/8$  the length of the shell (from the anterior) which fits into the RV behind a more gentle anteromedial protrusion of the RV margin. In dorsal view: subcuneate; narrowing anteriorly to a distinct terminal lip (formed by the anteromarginal ridges); greatest breadth at the subtruncate posterior. Sex dimorphism marked, males shorter and much narrower posteriorly than females which possess the usual two internal cavities in the rear of each valve.

DIMENSIONS: Holotype, adult ♀, Nat. Mus. Vic. Reg. No. J35: length 0.70 mm, height 0.40 mm, breadth 0.29 mm; Paratype, adult ♀ (disarticulated), Nat. Mus. Vic. Reg. No. J36: length 0.66 mm, height 0.36 mm; Paratype, adult ♂, Nat. Mus. Vic. Reg. No. J36: length 0.66 mm, height 0.36 mm, breadth 0.21 mm.

TYPE LOCALITY: Swash mark, Ricketts Point.

REMARKS: Keij (1953, p. 156-157, Pl. 1, figs. 1a-b) and van den Bold (*op. cit.*) have discussed and figured species with a similar hingement from eastern Indonesia and New Zealand respectively. This species is in appearance quite unlike Keij's species. It closely resembles the species figured by van den Bold, however, in such features as the ornament of ridges. Possibly, the anterodorsal sinuosity is not as pronounced as in the New Zealand form which also appears to be more coarsely pitted over the surface and more coarsely denticulate anteromarginally.

DISTRIBUTION: New Zealand (?) to south-eastern Australia.

Suborder PODOCOPINA Sars, 1866

Superfamily BAIRDIACEA Sars, 1888

Family BAIRDIIDAE Sars, 1888

Genus **Bairdia** McCoy 1844

***Bairdia* sp.**

(Fig. 2a)

(?) *Bairdia fusca* Brady, 1866; Brady, 1880, p. 49, Pl. 7, figs. 2a-d (not *fusca*).

MATERIAL: Seaholme, 2 individuals; Ricketts Point, 10 individuals.

**DIAGNOSIS:** Shell medium-large; subtrapezoidal (bairdioid) in lateral view; surface punctate, and hirsute in well preserved individuals, valves denticulate posteroventrally; LV larger than RV, overlapping it strongly in the dorsal region and also ventrally via a median flap; greatest height approximately medial in LV, but anteromedial in RV. Internally: lamellae broad, with large anterior and posterior vestibules; radial pore canals fairly numerous, short and straight; normal pore canals very numerous, pin-shaped, simple; 9 muscle scars arranged in the usual rosette pattern; hingement of ridge and groove type (without terminal teeth or crenulations). In dorsal view: elliptical, with sub-equally acuminate extremities; greatest breadth medial, less than half the height; LV overlap responsible for asymmetry of the valves. Anatomically: not known. Sex dimorphism present, females higher than males.

**DIMENSIONS:** Nat. Mus. Vic. Reg. No. J37: length 0.90 mm, height 0.56 mm, breadth 0.39 mm; one broken specimen has a length of 0.92 mm.

**LOCALITY:** Swash mark, Ricketts Point.

**REMARKS:** Possibly, a form similar to this (collected at Pork Jackson 'Challenger' Station, April 20th, 1874) was identified by Brady with *B. fusca* which he had established previously (1866, p. 364, Pl. 57, figs. 9a-d) from Australian material. The type of *B. fusca*, however, differs from the present species in general shape, patch pattern and muscle scar pattern. Thus it would appear that this species is new, but I am unwilling to base a new name on the specimens available which are all juveniles.

**DISTRIBUTION:** South-eastern Australia.

Superfamily CYPRIDACEA Baird, 1845

Family CYPRIDIDAE Baird, 1845

Subfamily MACROCYPRIDINAE Müller, 1912

Genus *Macrocypris* Triebel 1960

*Macrocypris* sp.

(?) *Macrocypris maculata* (Brady), 1866; 1880, p. 18.

**MATERIAL:** Ricketts Point, one damaged LV.

**DIMENSIONS:** Nat. Mus. Vic. Reg. No. J38: length (estimated) 1.06 mm, height 0.54 mm.

**REMARKS:** Triebel's recognition of this genus has paved the way for revision of the hoary practice in Victoria of assigning all large lozenge-shaped ostracodes to *Macrocypris* Brady, and worse, to the same species, *M. decora* (Brady), 1866, whether they be of Eocene, Middle or Upper Tertiary or of Recent age. In fact all belong in *Macrocypris* (usually characterized externally by three discoloured patches on each valve) and exhibit considerable speciation throughout the Tertiary and into the Recent. The genus is usually encountered in temperate to tropical shallow water open ocean environments.

**DISTRIBUTION:** South-eastern Australia.

Subfamily PARACYPRIDINAE Sars, 1923

Genus *Paracypris* Sars 1866

*Paracypris bradyi* sp. nov.

(Fig. 2d)

(?) *Paracypris polita* Sars, 1866; Brady, 1880, p. 20.

DERIVATION OF NAME: For George Stewardson Brady, F.R.S. (1832-1921), the pioneer in research on Australian marine ostracodes.

MATERIAL: Seaholme, 8 individuals; Ricketts Point, 29 individuals.

DIAGNOSIS: Shell medium-large; shape elongate-subtriangular in lateral view; surface smooth; colour pale yellowish-brownish; dorsal margin convex, slightly inflexed anterodorsally; anterior margin broadly rounded; ventral margin sinuated medially; posterior subacuminate; greatest height anteromedial, about  $\frac{2}{3}$  the length. Internally: lamellae broad anteriorly and posteriorly, narrow ventrally; anterior and posterior vestibules prominent; radial pore canals characteristically branched anteriorly, simple posteriorly; normal pore canals scattered, simple; muscle scars typical, as illustrated; ridge and groove hingement. In dorsal view elliptical, narrow; greatest breadth anteromedial; extremities subacuminate. Anatomically: not known. Sex dimorphism not noted.

DIMENSIONS: Holotype, Nat. Mus. Vic. Reg. No. J39: length 0.78 mm, height 0.29 mm, breadth 0.24 mm; Paratype, Nat. Mus. Vic. Reg. No. J40: length 0.80 mm, height 0.30 mm, breadth 0.24 mm.

TYPE LOCALITY: Swash mark, Ricketts Point.

REMARKS: *Paracypris* is known to be cosmopolitan and most records hitherto (cf. Brady, *op. cit.*) have been referred to the type species. However, at least 3 other species are known from Recent seas. These are: *Paracypris* spec. (Hartmann 1962, p. 176), which occurs off the coast of Chile and may range to Scammon Lagoon, Baja California (McKenzie & Swain, in press), and *Paracypris* spp. (2 species) from Sahul Shelf, off north-western Australia. The Victorian species can be easily differentiated from these on the grounds of shape, size and radial pore canal branching pattern, and is similarly distinguished from Sars' type species as illustrated by him (Sars 1923, Pl. 31). It is noteworthy that these other species all come from sub-littoral to neritic environments which may necessitate modification of the current opinion (van Morkhoven 1963, p. 80) that the genus occurs mainly in deeper (infraneritic to bathyal) waters. It is likely that the controlling factor on the occurrence of *P. bradyi* in Port Phillip Bay is the phytobenthos.

DISTRIBUTION: (?) New Zealand (Wellington Harbour) to south-eastern Australia.

### Genus *Phlyctenophora* Brady 1880

#### *Phlyctenophora* sp.

MATERIAL: Ricketts Point, 2 individuals.

DIMENSIONS: 1st stage juvenile, Nat. Mus. Vic. Reg. No. J41: length 0.90 mm, height 0.43 mm, breadth 0.35 mm.

LOCALITY: Swash mark, Ricketts Point.

REMARKS: Although it is often considered congeneric with, and a junior synonym of, *Paracypris* Sars (Müller 1912, p. 126, Hartmann 1963, p. 125) I follow van Morkhoven (1963, p. 83) in retaining this genus, since an examination of several species from each of the two genera has confirmed the marked differences in shape, muscle scar pattern and inner lamellae noted by him. Additional to these are the anatomical differences upon which Brady based his new category (1880, p. 32).

DISTRIBUTION: Southern Australia(?).

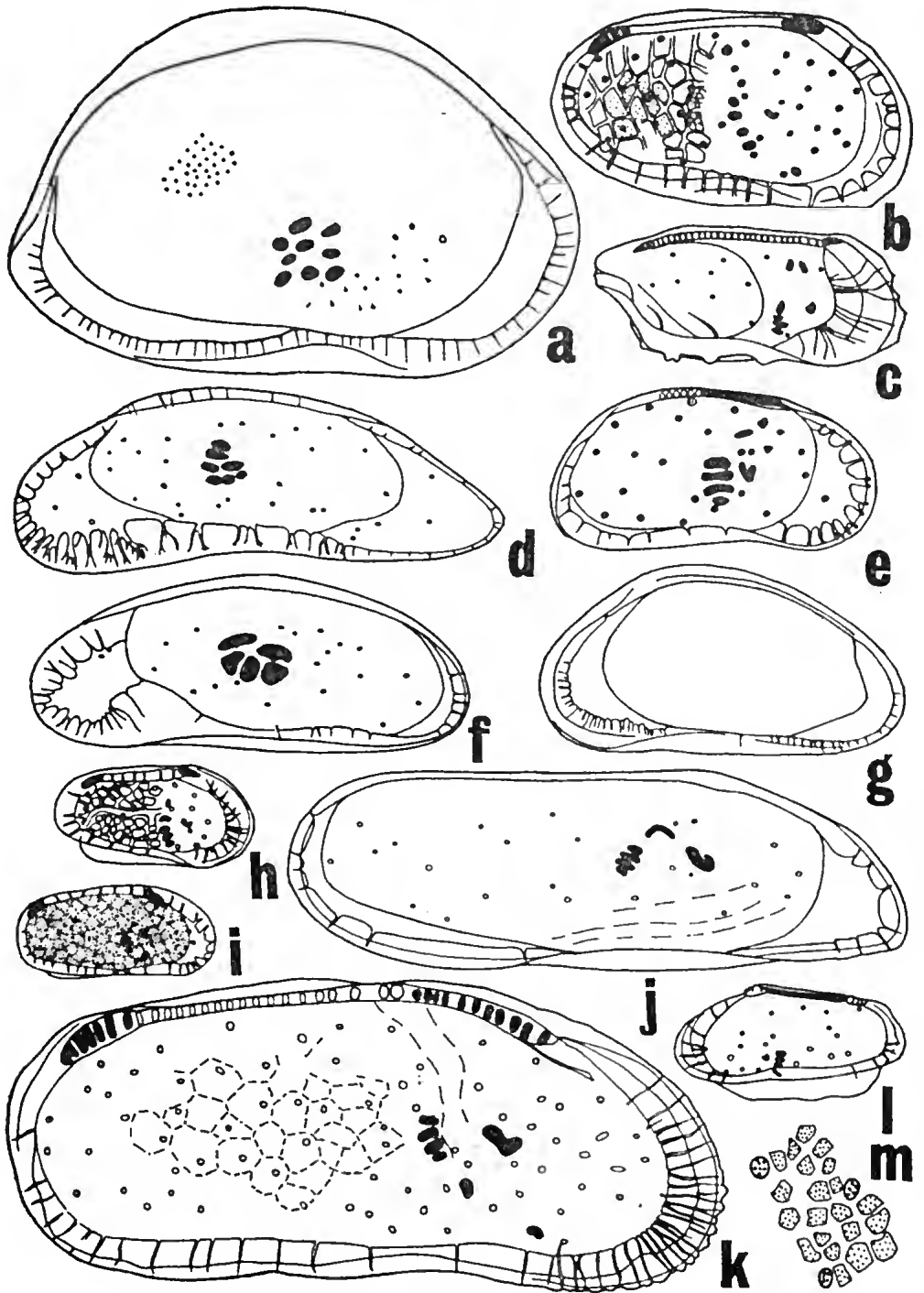


FIG. 2 →

## Subfamily PONTOCYPRIDINAE Müller, 1894

Genus *Propontocypris* Sylvester-Bradley 1948*Propontocypris* sp.

(Fig. 2g)

MATERIAL: Ricketts Point, 4 individuals.

DIMENSIONS: Juveniles, Nat. Mus. Vic. Reg. No. J42: length 0.54 mm, height 0.28 mm, breadth 0.21 mm.

LOCALITY: Swash mark, Ricketts Point.

REMARKS: The brownish-coloured individuals collected all proved to be juveniles. This is another genus in which distribution appears to be controlled by the phytobenthos.

DISTRIBUTION: South-eastern Australia.

Genus *Australoecia* gen. nov.DERIVATION OF NAME: *L. Australis* = southern; *Gk oikos* = habitat.TYPE SPECIES: *Australoecia victoriensis* sp. nov.

DIAGNOSIS: A pontocypridinid genus with a strong carapace of medium-large size, elongate-oval shape, broadly rounded extremities and smooth surface; RV larger than LV; height less than or equalling half the length in all known species; inner lamellae broad, especially anteriorly where there is a large vestibule; radial pore canals usually branched; normal pore canals simple; hinge adont; muscle scars large, 5 in number, arranged in a characteristic radial pattern; in ventral view displaying significant RV overlap.

REMARKS: Unfortunately, after opening several specimens, only fragmentary portions of the anatomy were recovered (Fig. 7, j-m). These show that both the palp of the male 2nd maxilla and the distal furca of the type species of *Australoecia* are most like those illustrated for *Argilloecia cylindrica* and *Argilloecia conoidea* (Sars 1923, Pl. 24, 25) and for the several *Argilloecia* species illustrated by Müller (1894, Pl. 12). There are small differences in these features, however, which suggest the distinctness of *Australoecia*. Palaeontologically, no confusion is possible since in strength of carapace, general shape, details of the inner lamellae, and strong ventral RV overlap *Australoecia* is unlike other genera in the subfamily, while its muscle scar pattern is unique.

DISTRIBUTION: Indo-Pacific to Australasia.

AGE: Tertiary to Recent.

FIG. 2—*a*, *Bairdia* sp., NMV J37, Internal LV, surface punctation indicated,  $\times 90$ . *b*, *Loxocythere harnibrooki* sp. nov., Holotype, NMV J45, Internal LV, surface ornament indicated posteriorly,  $\times 90$ . *c*, *Semicytherura* sp., NMV J55, Internal LV,  $\times 90$ . *d*, *Paracypris bradyi* sp. nov., paratype, NMV J40, Internal RV,  $\times 90$ . *e*, *Parakriihella australis* sp. nov., Holotype, NMV J50, Internal LV,  $\times 90$ . *f*, *Australoecia victoriensis* gen. et sp. nov., paratype, NMV J44, Internal RV,  $\times 90$ . *g*, *Propontocypris* sp., NMV J42, Internal RV, muscle scars not shown,  $\times 90$ . *h*, *Microcytherura gawemuelleri* sp. nov., Paratype, NMV J67, Internal LV, surface ornament indicated posteriorly,  $\times 90$ . *i*, *Microcytherura tricbeli* sp. nov., Paratype, NMV J69, Internal LV, surface ornament indicated posteromedially,  $\times 90$ . *j*, *Copypus rara* sp. nov., Holotype, NMV J49, Internal LV, ventral striations indicated,  $\times 90$ . *k*, *Australocytheridca vandenboldi* gen. et sp. nov., Holotype, NMV J47, Internal LV, surface ornament indicated,  $\times 90$ . *l*, *Microcytherura australis* sp. nov., Holotype, NMV J64, Internal RV,  $\times 90$ . *m*, *M. australis*, same specimen, detail of surface reticulation and normal pore canals,  $\times 180$ .

***Australoecia victoriensis* sp. nov.**

(Fig. 2f, Fig. 7 j-m)

DERIVATION OF NAME: For the State of Victoria.

MATERIAL: Seaholme, 8 individuals; Ricketts Point, 4 individuals.

DIAGNOSIS: A species of *Australoecia* characterized by medium size; narrowly oblong shape in lateral view; smooth, glistening surface; creamy white to brownish colour; RV overlapping LV around the entire periphery, especially medioventrally; dorsal margin gently arched; ventral margin nearly straight, inflexed anteromedially; anterior rounded, narrower than the broadly rounded posterior; greatest height approximately medial, less than half the length. In dorsal view elliptical; greatest breadth medial, less than the height; ends equally subaeuminate. Internally: lamellae broad anteriorly, narrower ventrally and posteriorly; vestibules prominent, especially in front where the line of conereseences is irregular and a deep anterior vestibule is present; radial pore canals moderately long, wavy and branched in front, but shorter and straighter ventrally and posteriorly; normal pore canals scattered, simple; hinge adont, articulation strong because of RV overlap; muscle scars large, situated centrally, 5 in number, grouped in a loose radial pattern. Anatomically: poorly known (see generic diagnosis above). Sex dimorphism not observed.

DIMENSIONS: Holotype, adult, Nat. Mus. Vic. Reg. No. J43: length 0.69 mm, height 0.28 mm, breadth 0.25 mm; Paratype, adult ♂, Nat. Mus. Vic. Reg. No. J44: length 0.65 mm, height 0.26 mm, breadth 0.24 mm.

TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: This species is distinguished from some others in the genus, all so far undescribed but known to occur in the Tertiary of Victoria and in the Indo-Pacific (Recent, Sahul Shelf), by its greater length/height ratio and different anterior radial pore canal branching pattern. Its appearance in dorsal view is sufficient to distinguish it from *Aglaia clavata* Brady, which probably also belongs in *Australoecia*.

Family CYTHERIDAE Baird, 1850

Subfamily CYTHERINAE Baird, 1850

Genus *Loxocythere* Hornibrook 1952***Loxocythere hornibrooki* sp. nov.**

(Pl. 11, fig. 2; Fig. 2b, Fig. 5e, Fig. 7a-i)

DERIVATION OF NAME: For N. de B. Hornibrook, the New Zealand micropalaeontologist.

MATERIAL: Seaholme, 6 individuals; Ricketts Point, 5 individuals.

DIAGNOSIS: A species of *Loxocythere* characterized by medium size; subquadrate shape in lateral view; reticulate carapace, in which the reticules themselves are micro-reticulate or micropunctate (observed under high power), some individuals developing a low posteroventral node; dorsal margin somewhat irregular, subparallel to the ventral margin which is slightly inflexed medially; anterior margin broadly rounded; posterior also broadly rounded but narrower than the anterior; height little more than half the length. In dorsal view: subovate; greatest breadth approximately medial, about half the length. Internally: lamellae moderately broad; anterior vestibule prominent, elongate; radial pore canals short, straight; normal pore canals scattered, sieve-like; hinge hemimerodont, RV with

crenulate terminal teeth and a smooth median furrow, LV complementary; muscle scars comprising 4 oval adductors, a heart-shaped antennal scar, a single mandibular near the anteroventral inner margin, a dorsal scar immediately above the adductors, and at least one other dorsal scar, near the dorsal margin. Anatomically: all limbs strongly developed; 1st antenna 5-jointed; 2nd antenna with a powerful exopodite, and 3 stout claws on the terminal joints of the endopodite; mandibular palp relatively weak, epipod with at least 5 strahlen, coxale strong; maxilla palp elongate-cylindrical, distal joint narrow, lobes similarly elongate-cylindrical; legs increasing in length towards the posterior, terminal claws stout and slightly hooked distally; brush shaped organs equal, less elongate than in *Cythere*; penis very large ( $245\mu$  in length) and structurally similar to the penis in *Cythere* species. Sex dimorphism not observed.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J45: length 0.55 mm, height 0.30 mm, breadth 0.29 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J46: as for the holotype.

**TYPE LOCALITY:** Swash mark, Ricketts Point.

**REMARKS:** This species differs from the type species, *L. crassa* Hornibrook, from *L. kingi* Hornibrook and from *L. inflata* Hanai, in shape (*L. crassa* and *L. kingi* are trapezoidal, *L. inflata* has a subacuminate posterior), strength of reticulation (stronger than *L. kingi* or *L. inflata* but weaker than *L. crassa*), and in possessing more radial pore canals and a larger anterior vestibule than any of them. The genus *Tetracytherura* Ruggieri has been put in synonymy with *Loxocythere* by Ruggieri (1959, p. 199) and Hanai (1959b, p. 414) although van Morkhoven (1963, p. 15) maintains that it is not synonymous with *Loxocythere*. However the matter be resolved, *Tetracytherura angulosa* Seguenza, the best known and type species of Ruggieri's genus also differs from the present species in its shape (trapezoidal), very weak reticulation, very small anterior vestibule and fewer radial pore canals.

The diagnosis above contains the first description of anatomic characters for *Loxocythere*. They show it to be a true cytherinid in all features, especially the remarkably large copulatory organs (cf. Sars 1925, p. 168, Pl. 77). This confirms the opinion arrived at earlier on palaeontological grounds by Hornibrook (1952, p. 30).

**DISTRIBUTION:** Southern Australia, from Oyster Harbour, near Albany, Western Australia, to Port Phillip Bay, Victoria.

#### Subfamily CYTHERIDEIDINAE Sars, 1925

##### Genus *Australocytheridea* gen. nov.

**DERIVATION OF NAME:** *L. Australis* = southern, and generic name *Cytheridea*.

**TYPE SPECIES:** *Australocytheridea vandenboldi* sp. nov.

**DIAGNOSIS:** A cytherideidinid genus characterized by large size; transversely oblong shape; denticulate anteroventral margin; dorsomedial sulcus; LV larger than RV; height usually less than half the length; pitted or reticulate surface ornamentation; moderately broad inner lamellae; absence of vestibules; long, wavy, typically unbranched radial pore canals; simple normal pore canals; muscle scars comprising 4 adductors, a V-shaped antennal scar and 2 widely spaced mandibulars; hinge modified antimerodont, consisting in LV of terminal crenulate sockets with a median crenulate bar, RV complementary, these elements strengthened (at least in the type

species) by internal antislip ridges. Sex dimorphism present, females shorter than males.

REMARKS: The shape of the new genus is intermediate between those of *Cyprideis* and *Haplocytheridea*, the two genera most closely allied to it. The hingement of the new genus, however, is modified antimerodont, unlike the entomodont hinge of *Cyprideis* or the holomerodont hinge of *Haplocytheridea* (Sandberg 1964, p. 358). Other Cytherideinid genera with antimerodont hingements (Hartmann 1963, p. 72) are easily distinguished from *Australocytheridea* on general shape and also by such features as size, absence of a suleus, ornamentation, marginal dentation, type of overlap, presence of vestibules, number and type of radial pore canals.

DISTRIBUTION: Southern Australia.

AGE: Neogene—Recent.

***Australocytheridea vandenboldi* sp. nov.**

(Pl. 11, fig. 13; Fig. 2k, Fig. 5j)

DERIVATION OF NAME: For Professor W. A. van den Bold, the ostracode taxonomist, Department of Geology, Louisiana State University.

MATERIAL: Seaholme, 13 individuals; Ricketts Point, 7 individuals.

DIAGNOSIS: A species of *Australocytheridea* with the following distinguishing characteristics: large size; transversely oblong shape in lateral view; surface ornamented everywhere but dorsally by broad shallow pits and a well-marked double sulcus with a narrow median ridge which runs from the mid-dorsum towards the centre of each valve; LV larger than RV, overlapping it dorsally and ventrally, with a slight anterodorsal lip; dorsal margin gently arched; ventral margin inflexed antero-medially; anterior rounded, denticulate anteroventrally, straight to slightly concave anterodorsally; posterior very broadly and evenly rounded; greatest height anteromedial; no eye tubercle or subcentral tubercle; length/height ratio is 2.5 (males), 2.4 (females). Internally: inner lamellae broader anteriorly than ventrally and posteriorly; inner margin and line of concrescence coincident; radial pore canals fairly numerous anteriorly (20-25) but few ventrally and posteriorly, straight to wavy, thickened through most of their length, but thinning near the list; selvage fairly distinct; flange narrow; normal pore canals scattered, simple, issuing near the centre of the surface pits (not along the intervening ridges); muscle scars consisting of 4 adductors, with a large broadly V-shaped antennal scar in front and a relatively large mandibular (?) in front and immediately below, with another smaller mandibular scar in front and further below (near the ventral margin), dorsal scars not observed; hinge modified antimerodont, consisting in LV of an elongate crenulate anterior socket, almost twice as long as the crenulate posterior socket, with an intervening median bar in which the anterior third is more broadly and irregularly crenulate, also slightly more raised, than the posterior portion, RV complementary with a smooth narrow antislip ridge, projecting forwards at a low angle from below the centre of the crenulate anterior element, which fits against a similar ridge in the LV. In dorsal view, the species is subelliptical; narrowing anteriorly, broadly rounded posteriorly; greatest breadth posteromedial, behind the sulcus. Sex dimorphism is evident, with females shorter than males. Anatomically: not known, only empty carapaces collected.

DIMENSIONS: Holotype, adult ♂, Nat. Mus. Vic. Reg. No. J47: length 1.08 mm, height 0.45 mm, breadth 0.41 mm; paratype, adult ♂, Nat. Mus. Vic. Reg. No. J48: length 1.09 mm, height 0.44 mm, breadth 0.41 mm; paratype, adult ♀, Nat. Mus. Vic. Reg. No. J48: length 1.00 mm, height 0.43 mm, breadth 0.41 mm.



TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: There are no described species with which this form can be confused, although it is slightly similar to species of *Cushmanidea* Blake, described from Japan (Hanai 1959a) and some species of *Haplocytheridea* described from the Americas (Sandberg 1964). The hingement, sulcus, lamellae, radial pore canals all separate the present species from these others.

*Australocytheridea* has yet to be collected from the open ocean, outside Port Phillip Bay, and may be restricted to protected shallow water marine environments. It is my opinion that *Australocytheridea* probably occupies in Australia the niche colonized by *Haplocytheridea* in America, but van den Bold (personal communication) feels that it would be more correct to posit that it occupies a niche similar to that of *Cushmanidea* in America.

DISTRIBUTION: Southern Australia.

Subfamily NEOCYTHERIDEIDINAE Puri, 1957

Genus *Copytus* Skogsberg 1939

*Copytus rara* sp. nov.

(Fig. 2j)

DERIVATION OF NAME: L. *Rara* = rare, for its infrequent occurrence in the collections.

MATERIAL: Seaholme, 3 individuals.

DIAGNOSIS: A species of *Copytus* characterized by medium-large size; narrowly elongate shape in lateral view; surface smooth, except ventrally in adults where there are several faint striae; dorsal margin straight; ventral margin parallel, inflexed anteromedially; anterior subacuminate; posterior broadly rounded; height subequal throughout the length, equalling about  $\frac{1}{3}$  the length. In dorsal view narrowly ovate; greatest breadth approximately medial. Internally: lamellae broad in front, narrower ventrally and behind; vestibules prominent, anterior vestibule broad, posterior vestibule elongate; radial pore canals few, short, straight; normal pore canals scattered, simple; hinge adont; muscle scars grouped anteromedially, comprising at least 4 adductors, a V-shaped antennal scar and an intermediate fulcral 'scar', mandibular and dorsal sears not seen. Anatomically: unknown. Sex dimorphism not observed.

DIMENSIONS: Holotype, adult LV, Nat. Mus. Vic. Reg. No. J49: length 0.95 mm, height 0.30 mm, breadth 0.30 mm.

TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: The simple normal pore canals and adont hinge separate this genus from *Neocytherideis* Puri (sieve-like normal pore canals, lophodont hinge, cf. van Morkhoven 1963, p. 331, 336). Previously, the only described species referred to *Copytus*, other than the type species, *C. caligula*, was *Cytherideis laevata* Brady, 1880 (cf. Skogsberg 1939, p. 425). Recently, another species, *Copytus elongata*, has been described (Benson 1964a, p. 16-17, Fig. 9). All three are smooth forms whereas *C. rara* is striate ventrally. A fourth undescribed species, from the Sahul Shelf, is much smaller than the present material, has a different radial pore canal pattern, and is not striate ventrally (Swain & McKenzie, unpublished data).

DISTRIBUTION: South-eastern Australia to New Zealand (collected off Three Kings Island, material supplied by Hornibrook).

## Subfamily KRITHINAE Mandelstam, 1958

Genus *Parakrithella* Hanai 1959*Parakrithella australis* sp. nov.

(Fig. 2e, Fig. 7 n-o)

*Parakrithella* sp. McKenzie, 1964, p. 448-453.DERIVATION OF NAME: *L. Australis* = southern.

MATERIAL: Seaholme, 7 individuals; Ricketts Point, 10 individuals.

DIAGNOSIS: A species of *Parakrithella* characterized by small-medium size, elongate—oblong shape in lateral view; smooth surface; pallid to pale brownish colour; dorsal margin straight; ventral margin inflexed anteromedially; anterior broadly rounded; posterior subeuncate; height subequal throughout the length and a little less than half the length. In dorsal view narrowly ovate; greatest breadth medial, about  $\frac{2}{3}$  the length. Internally: lamellae broad anteriorly, narrow ventrally and posteriorly; anterior vestibule large, line of conerescence scalloped; posterior vestibule elongate, narrow; radial pore canals fairly numerous, branched anteromarginally; normal pore canals scattered, sieve-like; hinge modified adont, in LV consisting of a long shallow crenulate anterior groove followed by a short crenulate bar (as illustrated), RV complementary; muscle scars large, comprising 4 adductors, a large V-shaped antennal scar, and 3 dorsal scars (mandibular not seen). Anatomically: imperfectly known, only fragments found in the specimens opened but the stout joints of the 2nd antenna endopodite are characteristic of this genus (Hartmann 1962, p. 191) and indeed of the subfamily. Sex dimorphism present, females higher and broader than males.

DIMENSIONS: Holotype, adult ♀, Nat. Mus. Vic. Reg. No. J50: length 0.50 mm, height 0.24 mm, breadth 0.20 mm; paratype, adult ♀, Nat. Mus. Vic. Reg. No. J51: length 0.48 mm, height 0.20 mm, breadth 0.18 mm; paratype, adult ♂, Nat. Mus. Vic. Reg. No. J51: length 0.49 mm, height 0.23 mm, breadth 0.19 mm.

TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: At least three species of *Parakrithella* have been described, two from the margins of the Pacific (Japan and Chile) while the third is known to occur in the faunules of Pacific Islands in the Indo-Pacific. This record extends the distribution of this genus to the Australian region. Although there are few obvious differences in external shell features, *Parakrithella australis* can be easily separated from *P. notadonta* Hanai, the type species, *P. hanai* Hartmann and *P. flavescens* (Brady) on the bases of its different radial pore canal and normal pore canal patterns.

DISTRIBUTION: Southern Australia, from Oyster Harbour, near Albany, Western Australia, to Port Phillip Bay, Victoria.

## Subfamily CYTHERURINAE G. W. Müller, 1894

Genus *Cytherura* Sars 1866*Cytherura taylori* sp. nov.

(Pl. 11, fig. 3; Fig. 3g, Fig. 9a-g)

DERIVATION OF NAME: For Mr D. J. Taylor, foraminiferan micropalaentologist and biostratigrapher, Victorian Mines Department.

MATERIAL: Seaholme, 17 individuals.

DIAGNOSIS: A *Cytherura* species of small size; subrectangular shape in lateral view; ventrally inflated (typical of the subfamily); with a finely reticulate surface,

further ornamented by a flexuous median riblet, a medioventral riblet and by one or two weak riblets near the ventral margin; dorsal and ventral margins subparallel, nearly straight; anterior broadly rounded; posterior produced in a short subdorsal cauda; height about half the length; eye tubercles weakly developed. In dorsal view subhastate; subaeuminate in front and terminating behind in the cauda; greatest breadth approximately medial, just over  $\frac{1}{2}$  the length. Internally: lamellae of moderate width anteriorly (typical of the genus) and deeply incurved posteriorly; vestibules absent; anterior radial pore canals short and wavy—some branched terminally—posterior radial pore canals few in number but including the long, wavy, terminally forked pore canal which characterizes this subfamily; normal pore canals obscure, apparently simple; LV hinge consisting of short, narrowly triangular furrows on either side of a median bar which is strongly crenulate (4 or 5 times) at either end and weakly crenulate in the middle, RV complementary; muscle scars comprising 4 adductors and an antennal sear, mandibular and dorsal sears not observed. Anatomically: 2nd antenna with an elongate, double-jointed exopodite; mandible coxale with powerful masticatory teeth, epipod a single long bristle; legs increasing in length posteriorly; with the usual hand-shaped posteroventral process and terminal bristle on the end of the female body; penis structure unknown. Sex dimorphism present, females broader and higher than males.

**DIMENSIONS:** Holotype, adult ♀, Nat. Mus. Vic. Reg. No. J52: length 0.38 mm, height 0.19 mm, breadth 0.20 mm; paratype, adult ♀, Nat. Mus. Vic. Reg. No. J53: as for holotype; paratype, adult ♂, Nat. Mus. Vic. Reg. No. J53; length 0.38 mm, height 0.16 mm, breadth 0.15 mm.

**TYPE LOCALITY:** Tide pool, Seaholme.

**REMARKS:** The species is easily distinguished, on surface ornamentation alone, from the Australian 'Challenger' species (Brady, 1880, p. 131, 134) and the several species described by Hornibrook (1952, p. 50, 51). The diversity of cytherurids in Port Phillip Bay is consistent with, and complements, their known diversity world-wide in shallow-water marginal environments.

**DISTRIBUTION:** South-eastern Australia.

**Genus *Semicytherura* Wagner 1957**

***Semicytherura cryptifera* (Brady) 1880**

(Pl. 11, fig. 4; Fig. 3e)

*Cytherura cryptifera* Brady, 1880, p. 134, Pl. 32, figs. 4a-c.

**MATERIAL:** Seaholme, 2 individuals.

**DIMENSIONS:** Hypotypes, Nat. Mus. Vic. Reg. No. J54; length 0.45 mm, height 0.23 mm, breadth 0.27 mm; length 0.43 mm, height 0.23 mm, breadth 0.24 mm.

**REMARKS:** The striking sculpture allows no doubt of the identity of this form with Brady's species. Internally, as the figure shows, it is a typical *Semicytherura*.

**DISTRIBUTION:** South-eastern Australia. The holotype came from Challenger Station 162, off East Moncoeur Island, Bass Strait.

***Semicytherura* sp.**

(Pl. 11, fig. 5; Fig. 2c)

**MATERIAL:** Ricketts Point, 1 adult LV.

**DIMENSIONS:** Nat. Mus. Vic. Reg. No. J55: length 0.46 mm, height 0.21 mm, breadth (estimated) 0.25 mm.

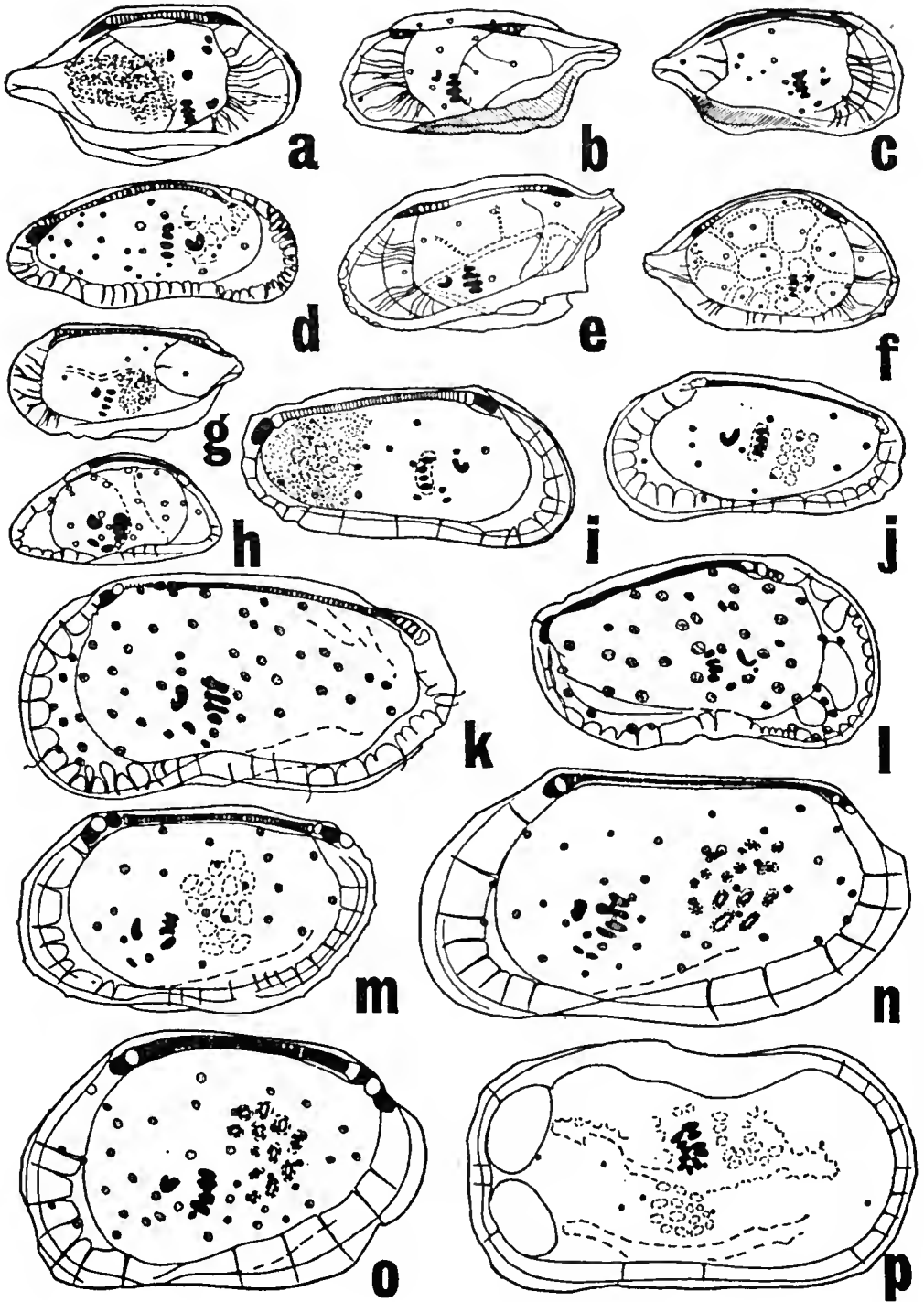


FIG. 3 →

REMARKS: The form is sufficiently distinct to separate this from all previously described Australasian species but unfortunately only the one empty valve was recovered. The figures are considered to be adequately descriptive for the present.

DISTRIBUTION: South-eastern Australia.

*Semicytherura tenuireticulata* sp. nov.

(Pl. 11, fig. 7; Fig. 3a)

DERIVATION OF NAME: For the fine surface reticulation—*L. tenuis* = fine, *L. reticulus* = a small net.

MATERIAL: Seaholme, 9 individuals; Ricketts Point, 3 individuals.

DIAGNOSIS: A *Semicytherura* characterized by small size; subovate shape in lateral view; surface ornamented mostly by a micropunctate fine reticulation but with weak anastomosing riblets present ventrally where the shell is inflated; dorsum arched; venter nearly straight; anterior rounded; posterior produced in a short subdorsal cauda; greatest height approximately medial, more than half the length. In dorsal view, lanceolate; greatest breadth medial, less than half the length. Internally: lamellae broad anteriorly and deeply incurved posteriorly; radial pore canals wavy, tending to be grouped anteriorly, few posteriorly (but including the usual long terminally forked pore canal); hinge slightly atypical, LV with terminal narrowly triangular grooves—weakly crenulate under high power observation—and a strong median bar, the ends of which are not conspicuously crenulate as in most species but appear to be weakly crenulate like the rest of the bar when viewed under high power; muscle scars comprising 4 adductors, an antennal scar and 4 dorsal scars, mandibular not seen; inner flange denticulate. Anatomically unknown. Sex dimorphism obscure.

DIMENSIONS: Holotype, adult, Nat. Mus. Vic. Reg. No. J56: length 0.46 mm, height 0.25 mm, breadth 0.20 mm; paratype, adult LV, Nat. Mus. Vic. Reg. No. J57: length 0.46 mm, height 0.25 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J57: length 0.45 mm, height 0.24 mm, breadth 0.21 mm.

TYPE LOCALITY: Tide pool, Seaholme.

FIG. 3—a, *Semicytherura tenuireticulata* sp. nov., Paratype, NMV J57, Internal LV, surface ornament indicated posteriorly,  $\times 90$ . b, *Semicytherura angusta* sp. nov., Holotype, NMV J58, Internal RV,  $\times 90$ . c, *Semicytherura paenunuda* sp. nov., Paratype, NMV J61, Internal LV,  $\times 90$ . d, *Leptocythere* cf. *vellicata* (Brady), Holotype, NMV J70, Internal LV,  $\times 90$ . e, *Semicytherura cryptifera* (Brady), Hypotype, NMV J54, Internal RV, trace of major ribs indicated,  $\times 90$ . f, *Hemicytherura seaholmensis* sp. nov., Paratype, NMV J63, Internal LV, surface ornament indicated,  $\times 90$ . g, *Cytherura taylori* sp. nov., Paratype, NMV J53, Internal RV, surface ornament indicated posteroventrally,  $\times 90$ . h, *Microcythere macphersoni* sp. nov., Paratype, NMV J99, Internal RV, trace of surface sulcus indicated,  $\times 90$ . i, '*Hemicytheridea*' *portjacksonensis* sp. nov., ♀ Hypotype, NMV J76, Internal LV, surface ornament indicated posteriorly,  $\times 90$ . j, '*H.*' *portjacksonensis*, ♂ Hypotype, NMV J76, Internal RV, surface ornament indicated posteriorly (micropunctuation not shown),  $\times 90$ . k, *Callistocythere insolita* sp. nov., Holotype, NMV J74, Internal RV,  $\times 90$ . l, *Callistocythere puri* sp. nov., Hypotype, NMV J71, Internal LV,  $\times 90$ . m, *Loxoconcha trita* sp. nov., Holotype, NMV J80, Internal RV, surface ornament indicated postero-medially,  $\times 90$ . n, *Loxoconcha australis* Brady, ♂ Hypotype, NMV J77, Internal RV, surface ornament indicated posteromedially,  $\times 90$ . o, *L. australis* Brady, ♀ Hypotype, NMV J77, Internal RV, surface ornament indicated posteromedially,  $\times 90$ . p, *Cytherelloidea keiji* sp. nov., Paratype, NMV J36, Internal LV, surface ornament indicated,  $\times 90$ .

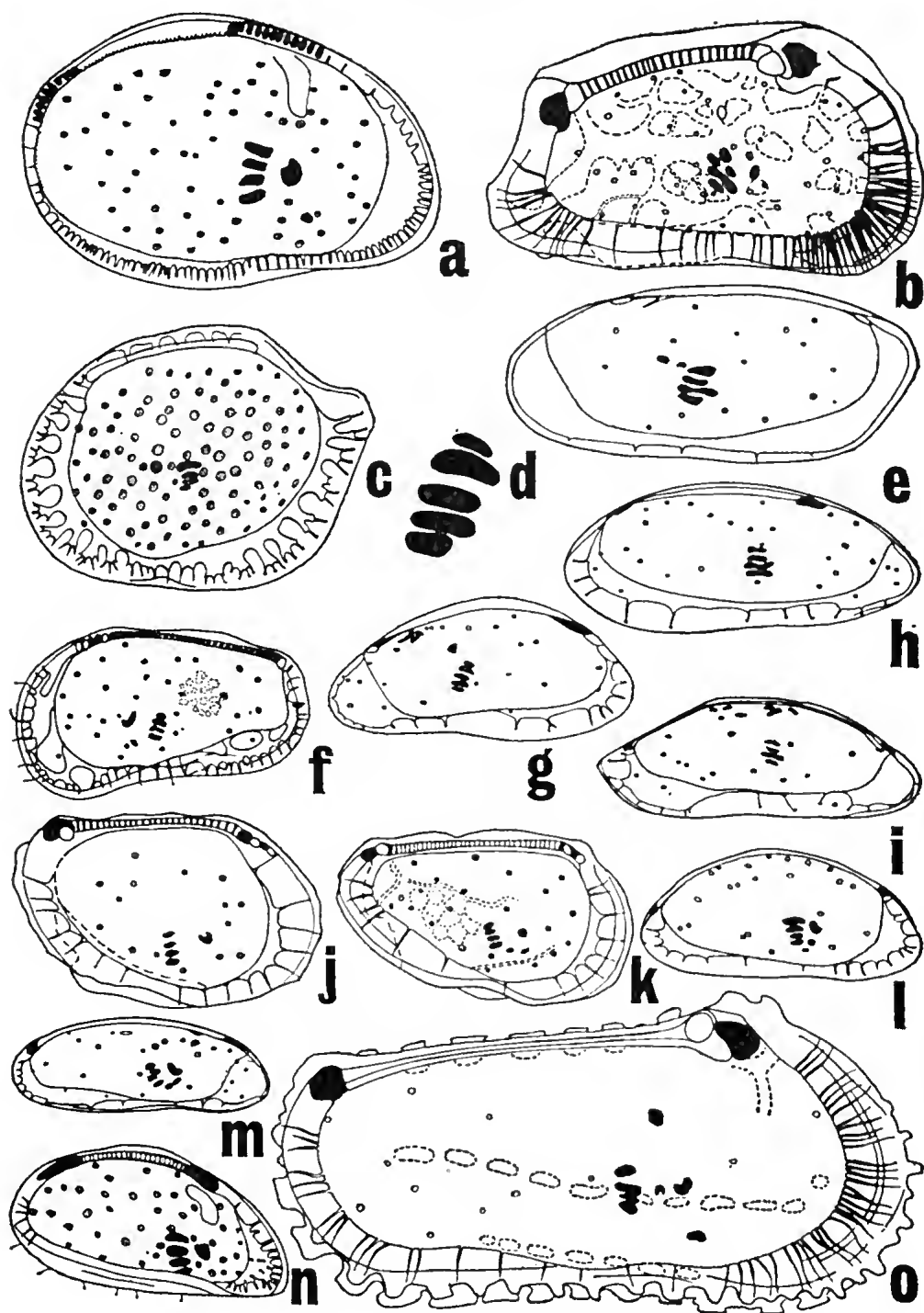


FIG. 4 →

REMARKS: The species is reminiscent of *S. mucronata* (Brady), 1880, described from Simons Bay, South-west Africa, in general shape and dorsal view but has a very different surface ornamentation. None of Hornibrook's New Zealand species resemble it at all.

DISTRIBUTION: South-eastern Australia.

*Semicytherura angusta* sp. nov.

(Pl. 11, fig. 6; Fig. 3b)

DERIVATION OF NAME: For its slender lateral and dorsal profiles—*L. angusta* = narrow.

MATERIAL: Seaholme, 4 individuals.

DIAGNOSIS: A species of *Semicytherura* characterized by small size; subrectangular shape in lateral view (discounting the prominent posterior caudal process); ornamentation consisting of a rib which forks medioventrally, one arm continuing ventrally the other trending posterodorsally, and a low rim which follows the dorsal and anterior margins, the rib obscure under reflected light but evident under transmitted light (specimen immersed in glycerine); dorsal and ventral margins subparallel, former straight, latter sinuated medially; anterior rounded, denticulate with up to 4 denticles; posterior produced in a long subdorsal cauda; height subequal throughout the length and less than  $\frac{1}{2}$  the length. In dorsal view subhastate; compressed anteriorly, each valve slightly depressed medially, and subtruncate posteriorly; cauda equalling  $\frac{1}{2}$  the length. Internally: as illustrated, typical of the genus, with terminal elements of the LV median bar strongly crenulate, rest of the bar weakly crenulate. Sex dimorphism present, females higher than males.

DIMENSIONS: Holotype, adult ♂, Nat. Mus. Vic. Reg. No. J58: length 0.43 mm, height, 0.18 mm, breadth 0.18 mm; paratype, adult ♀, Nat. Mus. Vic. Reg. No. J59: length 0.43 mm, height 0.20 mm, breadth 0.16 mm.

TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: The shape of this species in lateral view recalls that of *Cytherura costellata* Brady, as figured by Hornibrook (1952, p. 50, Pl. 14, figs. 229, 230, 233, 234), probably not the same species as Brady's (1880, p. 134, Pl. 32, figs. 7a-d) which was collected at Balfour Bay, Kerguelen Island, 'Challenger' Station 149. The surface ornamentation of this species, however, and its appearance in dorsal view differ considerably from both these forms.

DISTRIBUTION: South-eastern Australia.

FIG. 4—a, *Xestoleberis tigrina* (Brady), ♀ Hypotype, NMV J105, Internal LV,  $\times 90$ . b, '*Ambostracon*' *pumila* (Brady), Hypotype, NMV J100, Internal LV, trace of surface ribbing indicated,  $\times 90$ . c, *Loxoconchella pulchra* sp. nov., ♀ Paratype, NMV J85, Internal RV,  $\times 90$ . d, *Paracytherois portphillipensis* sp. nov., Holotype, NMV J96, detail adductor muscle scars,  $\times 180$ . e, *Paradoxostoma romei* sp. nov., Paratype, NMV J87, Internal RV,  $\times 90$ . f, *Callistocythere hartmanni* sp. nov., Holotype, NMV J72, Internal RV,  $\times 90$ . g, *Paracytherois portphillipensis* sp. nov., Holotype, NMV J96, Internal RV,  $\times 90$ . h, *Paradoxostoma commune* sp. nov., Topotype, Internal LV,  $\times 90$ . i, *Paradoxostoma trapezoideum* sp. nov., Topotype, Internal LV,  $\times 90$ . j, *Loxoconcha* cf. *variolata* Brady, Hypotype, NMV J79, Internal LV,  $\times 90$ . k, *Loxoconcha gilli* sp. nov., Paratype, NMV J83, Internal LV, surface ornament partly indicated,  $\times 90$ . l, *Cytherois dissimilis* sp. nov., Holotype, NMV J92, Internal LV,  $\times 90$ . m, *Cytherois bonaducei* sp. nov., Paratype, NMV J95, Internal LV,  $\times 90$ . n, *Xestoleberis briggsi* sp. nov., Holotype, NMV J106, Internal LV,  $\times 90$ . o, *Ponticocythereis militaris* (Brady), gen. nov. ♂ Hypotype, NMV J104, Internal LV, trace of ridges indicated,  $\times 90$ .

***Semicytherura paenenuda* sp. nov.**

(Fig. 3c)

DERIVATION OF NAME: For its almost bare surface—*L. paene* = almost, *L. nuda* = naked.

MATERIAL: Seaholme, 5 individuals.

DIAGNOSIS: A species of *Semicythereura* of small size; subquadrate shape in lateral view; RV distinctly larger than LV, overlapping it dorsally; bare of surface ornamentation except for a few indistinct anteroventral riblets; dorsal margin convex, more strongly so in RV; venter sinuated medially; anterior broadly rounded, posterior produced in a short mediodorsal process; greatest height medial, about half the length. In dorsal view sublanceolate; greatest breadth medial; anterior flattened terminally. Internally: posterior lamellae not incurved as deeply as in the species described above; median bar of the LV hingement crenulate throughout, scarcely differentiated terminally; otherwise similar to previous species. Anatomically not known. Females shorter and relatively higher than males.

DIMENSIONS: Holotype, adult ♂, Nat. Mus. Vic. Reg. No. J60: length 0·39 mm, height 0·19 mm, breadth 0·15 mm; paratype, adult ♀, Nat. Mus. Vic. Reg. No. J61: length 0·36 mm, height (LV) 0·17 mm, (RV) 0·19 mm, breadth 0·15 mm; paratype adult ♂, Nat. Mus. Vic. Reg. No. J61: length 0·38 mm, height 0·19 mm, breadth 0·16 mm.

TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: In length this species could be confused with a 1st stage instar of *S. tenuireticulata* but, apart from its ornamentation, can be differentiated by its narrower posterior lamellae (in which the upper radial pore canals trend towards the cauda rather than posteroventrally), thicker anterior radial pore canals, and longer LV hinge bar.

DISTRIBUTION: South-eastern Australia.

Genus ***Hemicytherura*** Elofson 1941

***Hemicytherura seaholmensis* sp. nov.**

(Pl. 11, fig. 8; Fig. 3f)

DERIVATION OF NAME: For the type locality.

MATERIAL: Seaholme, 25 individuals.

DIAGNOSIS: A *Hemicytherura* species of small size; subovate shape in lateral view; ornamented by broad, deep reticules; colour brownish; RV higher than LV, overlapping it dorsally; dorsum strongly arched; venter nearly straight; anterior rounded, narrowing anteroventrally where it is denticulate (3 or 4 denticles); posterior produced in a short mediodorsal process; greatest height approximately medial, about  $\frac{3}{8}$  the length. In dorsal view sublanceolate; compressed. Internally: lamellae moderately broad, inner margin regular; radial pore canals wavy, grouped (especially anteroventrally); normal pore canals scattered, simple; LV hinge consisting of weakly crenulate, narrowly triangular terminal furrows and a strong median bar, smooth in the middle but strongly crenulate at each end; muscle scars comprising 4 adductors and a single rounded antennal scar, mandibular and dorsal scars not seen. Anatomically unknown. Females slightly shorter and higher than males.

DIMENSIONS: Holotype, adult ♂, Nat. Mus. Vic. Reg. No. J62: length 0·39 mm, height 0·23 mm, breadth 0·16 mm; paratype, adult ♀, Nat. Mus. Vic. Reg. No.



J63: length 0.37 mm, height 0.24 mm, breadth 0.16 mm; paratype, adult ♂, Nat. Mus. Vic. Reg. No. J63: length 0.38 mm, height (LV) 0.21 mm, (RV) 0.23 mm, breadth 0.16 mm.

TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: Several species closely resemble the form described above. They include: *H. cellulosa* (Norman), *H. videns videns* (Müller), *H. videns aegyptica* Hartmann, and *H. cranekeycensis* Puri, from the North Atlantic, Mediterranean, Red Sea and coast of Florida respectively. The species group, therefore, has a cosmopolitan distribution and is commonly associated with the algal phytobenthos in shallow water (often protected) marginal marine environments. The present species is defined on the basis of consistent differences in surface ornamentation (number and shape of reticules) with respect to other members of the group. The closest New Zealand species are *H. fereplana* Hornibrook and *H. pentagona* Hornibrook. The first of these has many more reticules posterodorsally than the present species, while the other has fewer reticules, and these arranged in a different pattern.

DISTRIBUTION: South-eastern Australia.

Genus *Microcytherura* G. W. Müller 1894

*Microcytherura australis* sp. nov.

(Pl. 11, fig. 11; Fig. 2 1-m)

DERIVATION OF NAME: *L. Australis* = southern.

MATERIAL: Seaholme, 36 individuals; Ricketts Point, 3 individuals.

DIAGNOSIS: A species of *Microcytherura* characterized by small size; heavily calcified shell; strong ventral inflation; subrectangular shape in lateral view; surface micropunctate and finely reticulate, with a prominent ventral ridge which reaches its peak posteroventrally; LV overlapping RV posterodorsally; dorsal and ventral margins straight, subparallel (especially in LV); anterior rounded; posterior more acuminate in RV than LV; greatest height medial, less than half the length. In dorsal view subtrullate; greatest breadth more than half the length. Internally: lamellae moderately broad; inner margin regular, coinciding with line of concrescence; radial pore canals unbranched, widened at their bases; normal pore canals, scattered, sieve-like; RV hinge consisting of crenulate anterior and posterior teeth with a weakly crenulate furrow between them, LV complementary; muscle scars including 4 adductors and an heart-shaped antennal scar, others not seen. Anatomically unknown. Sex dimorphism weakly developed, males less broad than females.

DIMENSIONS: Holotype, adult ♂, Nat. Mus. Vic. Reg. No. J64: length 0.35 mm, height 0.16 mm, breadth 0.20 mm; paratype, adult ♂, Nat. Mus. Vic. Reg. No. J65: length 0.34 mm, height 0.16 mm, breadth 0.20 mm; paratype, adult ♀, Nat. Mus. Vic. Reg. No. J65: length 0.35 mm, height 0.17 mm, breadth 0.23 mm.

TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: This species is separated from others in the genus by its greater length/height ratio, weakly crenulate median hinge element and distinctive surface ornamentation. The heavily calcified shell of this and the next species is not typical in *Microcytherura* which is usually described as possessing a somewhat fragile to moderately calcified carapace. Further, the median hinge element of *Microcytherura* species is usually smooth. In other features, however, such as type of ornamentation, ventral inflation, inner lamellae, radial pore canals, normal pore canals and muscle scars, these species conform with typical *Microcytherura*.

DISTRIBUTION: South-eastern Australia.

***Microcytherura gawemuelleri* sp. nov.**

(Pl. 11, fig. 12; Fig. 2h; Fig. 5c)

DERIVATION OF NAME: For G. W. Müller who first defined the genus.

MATERIAL: Seaholme, 7 individuals; Ricketts Point, 3 individuals.

DIAGNOSIS: A species of *Microcytherura* of small size; subquadrate shape in lateral view; heavily calcified shell characterized by strong ventral inflation; surface ornament of numerous, closely set, small, deep pits and a median riblet which makes an 'U' in the posteroventral part of the carapace; posterior subtruncate in LV, but produced in a weak medioventral cauda in RV; greatest height anteromedial, about half the length. In dorsal view subdeltoid in shape; valve outlines inflexed behind points of greatest breadth. Internally: generally similar to the previous species but with a stronger hinge, a questionable anterior vestibule (very small if present), and a single dorsal muscle scar in addition to the scars described for *M. australis*. Anatomically unknown. Sex dimorphism not observed.

DIMENSIONS: Holotype, adult, Nat. Mus. Vic. Reg. No. J66: length 0·31 mm, height 0·15 mm, breadth 0·21 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J67: length 0·30 mm, height 0·15 mm, breadth 0·20 mm.

TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: The ornamentation distinguishes this species from *M. nigrescens* Müller (the type species), *M. fulva* (Brady and Robertson), and the previous species.

DISTRIBUTION: South-eastern Australia.

***Microcytherura triebeli* sp. nov.**

(Fig. 2i)

DERIVATION OF NAME: For Professor Erich Triebel, who kindly provided comparative data on the genus *Nannocythere* Schafer.

MATERIAL: Seaholme, 9 individuals.

DIAGNOSIS: A species of *Microcytherura* characterized by small size; elongate oblong shape in lateral view; ventral inflation; finely reticulate and micropunctate surface ornamentation; subparallel dorsal and ventral margins; broadly rounded anterior; subtruncate posterior; height less than half the length. In dorsal view narrowly subovate; greatest breadth posteromedial; anterior subeuminate; posterior rounded. Internally: lamellae moderately broad anteriorly, narrower ventrally and posteriorly; anterior vestibule well developed; radial pore canals short, widened at their bases; normal pore canals scattered, open (?); RV hinge with crenulate terminal teeth and a (?) weakly crenulate medial furrow, LV complementary; muscle scars consisting of 4 adductors, an antennal scar and two mandibulars, dorsal scars not seen. Anatomically unknown. Sex dimorphism present, males smaller than females.

DIMENSIONS: Holotype, adult ♀, Nat. Mus. Vic. Reg. No. J68: length 0·33 mm, height 0·15 mm, breadth 0·15 mm; paratype, adult ♂, Nat. Mus. Vic. Reg. No. J69: length 0·26 mm, height 0·14 mm, breadth 0·14 mm; paratype, adult ♀, Nat. Mus. Vic. Reg. No. J69: length 0·30 mm, height 0·14 mm, breadth 0·14 mm.

TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: The prominent anterior vestibule is diagnostic in separating this genus from the other *Microcytherura* spp. described here, on shell characters.

DISTRIBUTION: South-eastern Australia.

Subfamily LEPTOCYTHERINAE Hanai, 1957

Genus *Leptocythere* Sars 1925

*Leptocythere* cf. *vellicata* (Brady) 1880

(Fig. 3d)

*Cythere vellicata* Brady, 1880, p. 64, Pl. 12, figs. 2a-d.

MATERIAL: Seaholme, 18 individuals.

DIMENSIONS: Hypotypes, adults, Nat. Mus. Vic. Reg. No. J70: length 0.44 mm, height 0.18 mm, breadth 0.16 mm; length 0.43 mm, height 0.19 mm, breadth 0.18 mm.

REMARKS: With few exceptions all the specimens examined bear some surface punctation, which Brady specifically excluded in his description. They are, however, so closely similar to his species (collected at Port Jackson, Sydney, April 20th, 1874) in other respects, that a tentative referral appears warranted.

DISTRIBUTION: South-eastern Australia.

Genus *Callistocythere* Ruggieri 1953

*Callistocythere puri* sp. nov.

(Pl. 12, fig. 2; Fig. 31)

*Cythere canaliculata* (Reuss), 1850; Brady, 1866, p. 373, Pl. 59, figs. 4a-f; 1880, p. 73, Pl. 14, figs. 7a-d (not *canaliculata*).

DERIVATION OF NAME: For Dr Harbans Puri of the Florida Geological Survey, who is at present revising Brady's 'Challenger' collection.

MATERIAL: Seaholme, 15 individuals; Ricketts Point, 10 individuals.

DIMENSIONS: Hypotypes, adults, Nat. Mus. Vic. Reg. No. J71: length 0.53 mm, height 0.30 mm, breadth 0.29 mm; length 0.51 mm, height 0.28 mm, breadth 0.28 mm.

REMARKS: The original specimen, upon which Brady based his identification, was collected at Hobsons Bay. The 'Challenger' material came from off East Monocoeur Island, Bass Strait, and from Port Jackson. It is evidently the same species as that from Hobsons Bay, but not the European Tertiary species described by Reuss, from which it can be distinguished readily on features of the surface ornamentation alone. On similar grounds, the Australian specimens can be separated from the Mediterranean Neogene-Recent species *Callistocythere flavidofusca* (Ruggieri), 1950, which has also been equated with Brady's Hobsons Bay form (Ruggieri 1953, p. 99).

DISTRIBUTION: South-eastern Australia to (?) New Zealand. (*Leptocythere* aff. *canaliculata* (Reuss), in Hornibrook 1952, p. 17).

*Callistocythere hartmanni* sp. nov.

(Pl. 12, fig. 5; Fig. 4f; Fig. 8 a-h)

DERIVATION OF NAME: For Dr Gerd Hartmann of the Hamburg Museum, presently working on the ostracode section of Bronn's 'Klassen des Tierreichs'.

MATERIAL: Seaholme, 8 individuals.

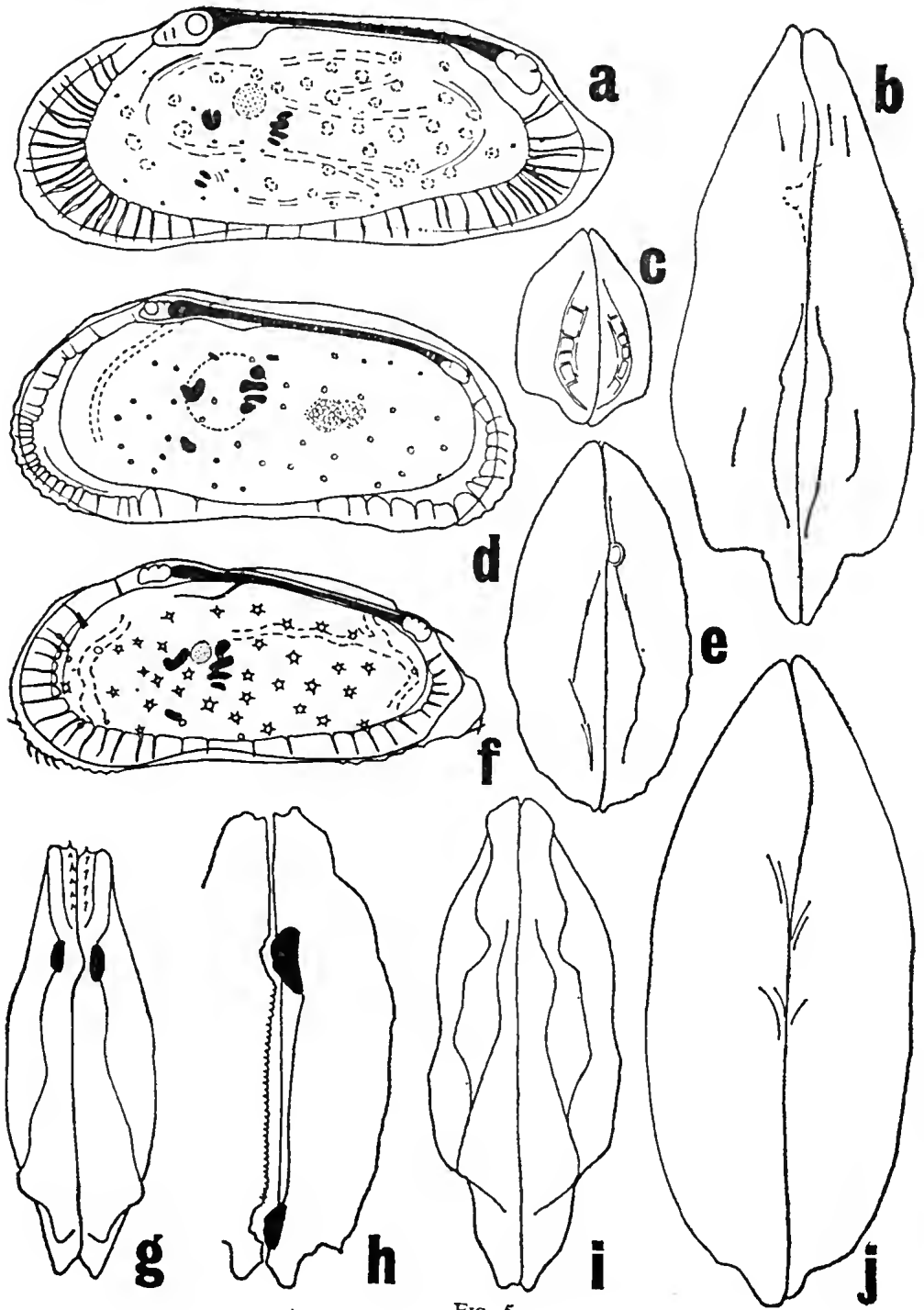


FIG. 5 →

**DIAGNOSIS:** A *Callistocythere* characterized by small-medium size; subquadrate shape, yellow-brownish colour; surface ornamentation a complex pattern of reticulations, ridges and furrows (as illustrated); dorsal margin slightly arched, inclined backwards; ventral margin sinuated medially; anterior broadly rounded; posterior rounded below, but making approximately a right angle with the dorsal margin posterodorsally; greatest height anteromedial, about  $\frac{2}{3}$  the length. In dorsal view narrowly subovate, greatest breadth approximately medial, slightly less than half the length. Internally: lamellae broad; vestibula exhibiting the lacunae typical of the genus in a pattern which is nearly constant for this species (hence important diagnostically at the species level); radial pore canals polyfurcated; normal pore canals scattered, sieve-like; RV hinge comprising an anterior element—consisting of 2 small rounded teeth followed by 2 small sockets and a final small tooth—a crenulate median furrow and a postjacent tooth, LV hinge complementary; muscle scars include 4 adductors, a V-shaped antennal scar and a single mandibular, dorsal scars not observed. Anatomically: 1st antenna with an elongate terminal joint; 2nd antenna exopodite double-jointed, reaching scarcely to the distal 2nd endopodite joint, terminal claws strong and serrate distally; lower lip adorned with a beard of long hairs, mandible palp well developed; legs increasing in size and strength posteriorly; end of the female body bearing a short spine. Sex dimorphism poorly developed.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J72: length 0.44 mm, height 0.25 mm, breadth 0.20 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J73: length 0.46 mm, height 0.26 mm, breadth 0.20 mm.

**TYPE LOCALITY:** Tide pool, Seaholme.

**REMARKS:** No species yet described resembles this either in surface ornamentation or internal features (lamellae particularly). The diversity of *Callistocythere* species also, in the protected environment afforded them by Port Phillip Bay, is similar to and complements their known diversity in such environments elsewhere (Müller 1894, Hanai 1957).

**DISTRIBUTION:** South-eastern Australia.

***Callistocythere insolita* sp. nov.**

(Pl. 12, fig. 1; Fig. 3k)

**DERIVATION OF NAME:** For its several atypical external and internal carapace features; *L. insolita* = unusual.

**MATERIAL:** Seaholme, 7 individuals; Ricketts Point, 6 individuals.

FIG. 5—a, *Doratocythere foveata* gen. et sp. nov., Holotype, NMV J107, Internal RV, surface pitting indicated,  $\times 90$ . b, *D. foveata*, same specimen before disarticulation, Dorsal view of carapace,  $\times 90$ . c, *Microcytherura gawemuelleri* sp. nov., Topotype, Dorsal view of carapace,  $\times 90$ . d, *Campylocytherid* sp., NMV J110, Internal RV,  $\times 90$ . e, *Loxocythere hornibrooki* sp. nov., Topotype, Dorsal view of carapace,  $\times 90$ . f, *'Doratocythere' venata* (Brady), Hypotype, NMV J109, Internal RV, showing star-shaped normal pore canals,  $\times 90$ . g, *Cletocythereis curta* sp. nov., Holotype, NMV J102, Dorsal view of carapace before disarticulation,  $\times 90$ . h, *'Doratocythere' venata* (Brady), Topotype, Dorsal view LV and RV, displaying hinge structure,  $\times 90$ . i, *'Ambostracon' pumila* (Brady), Hypotype, NMV J100, Dorsal view of carapace,  $\times 90$ . j, *Australocytheridea vandenboldi* gen. et sp. nov., ♀ Paratype, NMV J48, Dorsal view of carapace,  $\times 90$ .

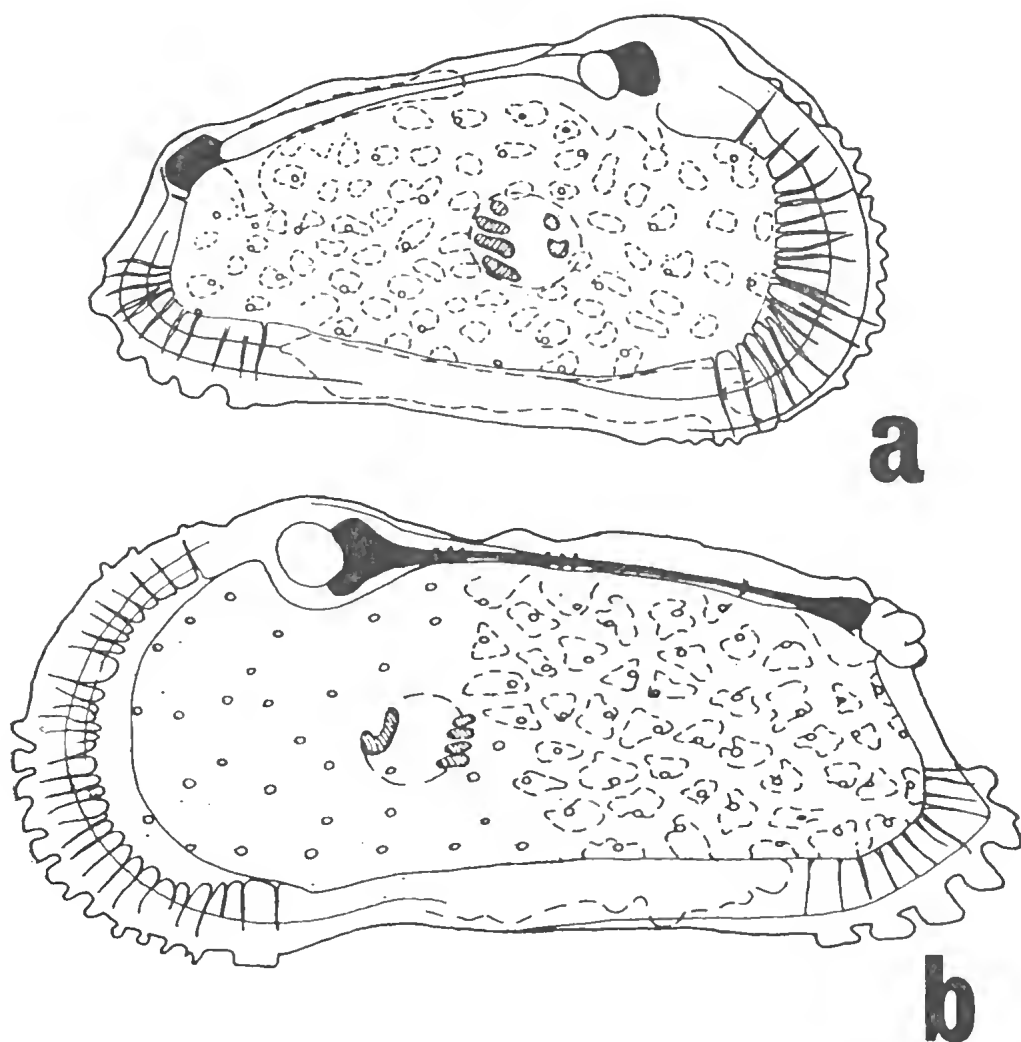


FIG. 6—*a*, *Cletocythereis curta* sp. nov., Holotype, NMV J102, Internal LV, surface ornament indicated,  $\times 90$ . *b*, *Cletocythereis* cf. *rastrumarginata* (Brady), ♂ Hypotype, NMV J101, Internal RV, surface ornament indicated posteriorly,  $\times 90$ .

DIAGNOSIS: A *Callistocythere* species of medium size; subquadrate shape; yellowish-brownish colour; ornamented by several irregular low transverse ribs, and ventrally, one or two riblets which follow the margin, two of the ribs rising to fairly sharp peaks posteromedially; dorsal margin almost straight, gently inclined backwards; ventral margin inflexed anteromedially; anterior broadly rounded; posterior higher in LV than RV; greatest height anteromedial, about half the length. In dorsal view subovate; tapering in front, subtruncate behind; greatest breadth less than half the length. Internally: without laeunae; anterior and posterior vestibules well developed; radial pore canals short, branched anteroventrally and

posteriorly; normal pore canals scattered, sieve-like; anterior element of RV hinge consisting of a socket, tooth, crenulate ridge and 3 sockets and followed by a postjaacent crenulate median furrow (which rises towards the rear) and a posterior tooth, LV hinge complementary; muscle scars typical of the genus. Anatomically, unknown. Sex dimorphism not noted.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J74: length 0.68 mm, height 0.34 mm, breadth 0.29 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J75: length 0.65 mm, height 0.34 mm, breadth 0.28 mm.

**TYPE LOCALITY:** Swash mark, Ricketts Point.

**REMARKS:** As far as the writer is aware, no other *Callistocythere* species has an external appearance resembling this species which is further differentiated by its atypical internal features (lamellae, vestibula, radial pore canals, hinge).

**DISTRIBUTION:** South-eastern Australia.

### Genus *Hemicytheridea* Kingma 1948

#### '*Hemicytheridea*' *portjacksonensis* sp. nov.

(Pl. 12, fig. 6; Fig. 3 i-j)

*Cythere demissa* Brady, 1868; 1880, p. 66, Pl. 12, fig. 7 a-j (not *demissa*)

*Hemicytheridea* sp.; McKenzie, 1964, p. 448-453.

**DERIVATION OF NAME:** For the locality at which the 'Challenger' types were collected.

**MATERIAL:** Seaholme, 34 individuals; Ricketts Point, 4 individuals.

**DIAGNOSIS:** A '*Hemicytheridea*' of small-medium size; elongate subrectangular shape; carapace strongly reticulate throughout, with a small oblong transverse depression in the muscle scar region; height greatest anteromedially, nearly half the length. In dorsal view elongate subovate; tapering frontwards, subtruncate posteriorly; greatest breadth medial, about equalling the height. Internally: lamellae broad; vestibules prominent; radial pore canals short, widened at their bases, unbranched; normal pore canals scattered, sieve-like; hinge antimerodont, LV with crenulate terminal sockets and a crenulate median bar; muscle scars comprising 4 adductors, a V-shaped antennal scar and single mandibular, dorsal scars not observed. Anatomically unknown. Sex dimorphism present, females broader than males (most noticeable in 1st stage juveniles).

**DIMENSIONS:** Hypotypes, adults, Nat. Mus. Vic. Reg. No. J76: length 0.53 mm, height 0.24 mm, breadth 0.25 mm; length 0.50 mm, height 0.24 mm, breadth 0.21 mm; 1st stage juvenile: length 0.46 mm, height 0.23 mm, breadth 0.24 mm.

**REMARKS:** *Cythere demissa* Brady, 1868 was described from Mauritius. The type slide contains 13 specimens referable to 4 species, only 2 individuals matching the type description and type illustration of *C. demissa* which is denticulate postero-ventrally. Neither the Victorian specimens, nor the 'Challenger' material referred by Brady to *C. demissa*, possess this feature, however, and they differ further from the lectotype in general shape, details of surface ornamentation and internal details. Specimens from Oyster Harbour, near Albany, Western Australian (McKenzie *op. cit.*) appear to be identical with the Victorian species, except that they are slightly smaller.

**DISTRIBUTION:** Southern Australia, (?) New Zealand (Hornibrook 1952, p. 17).

## Subfamily LOXOCONCHINAE Sars, 1925

Genus *Loxoconcha* Sars 1866*Loxoconcha australis* Brady 1880

(Pl. 12, figs. 10, 11; Fig. 3n-o, Fig. 9h-s)

*Loxoconcha australis* Brady, 1880, p. 119, Pl. 28, figs. 5a-f, Pl. 29, figs. 3a-d. *Loxoconcha* sp. 1 McKenzie, 1964, p. 448-453.

MATERIAL: Seaholme, 14 individuals; Ricketts Point, 15 individuals.

DIMENSIONS: Hypotypes, adult ♀, Nat. Mus. Vic. Reg. No. J77: length 0.70 mm, height 0.40 mm, breadth 0.36 mm; adult ♂, Nat. Mus. Vic. Reg. No. J77: length 0.76 mm, height 0.40 mm, breadth 0.36 mm.

REMARKS: The 'Challenger' specimens came from Port Jackson and off Booby Island, and the species also occurs in Oyster Harbour, Western Australia, so that the present records bridge neatly the gap in the distribution of this species.

DISTRIBUTION: Southern, south-eastern and (?) eastern Australia. It has also been recorded from Noumea (Brady 1890, p. 507, 520) but on examining the Noumean types these were found to differ consistently in shape and surface reticulation from the southern Australian material.

*Loxoconcha* sp.

(Pl. 11, fig. 9)

MATERIAL: Seaholme, 1 individual; Ricketts Point, 1 individual.

DIAGNOSIS: A *Loxoconcha* of medium size; subrhomboid shape; finely pitted surface ornament; with a flattened eye tubercle; greatest height medial, about half the length. In dorsal view labiate (slightly depressed medially); greatest breadth about  $\frac{2}{3}$  the height. Internally and anatomically not known.

DIMENSIONS: Adult, Nat. Mus. Vic. Reg. No. J78: length 0.64 mm, height 0.33 mm, breadth 0.23 mm.

LOCALITY: Swash mark, Ricketts Point.

REMARKS: This species belongs in the same group as *L. elliptica* Brady, *L. turbida* Müller, and *L. lenticulata* LeRoy, but can be readily distinguished from these species by its surface ornamentation pattern and distinctive appearance in dorsal view.*Loxoconcha* cf. *variolata* Brady 1878

(Pl. 12, fig. 3; Fig. 4j)

*Loxoconcha variolata* Brady, 1878, p. 400, Pl. 68, figs. 4a-d; 1880, p. 121, Pl. 29, figs. 6a-d.

MATERIAL: Seaholme, 9 individuals, Ricketts Point, 18 individuals.

DIAGNOSIS: A *Loxoconcha* of medium size; subrhomboid shape; inflated ventrally; surface reticulate, marked by a sharp posteroventral peak (ventrally the reticulations are arranged longitudinally); with a weak eye tubercle; height more than half the length. In dorsal view subhastate; greatest breadth posteromedial, equal to the height. Internally: lamellae broad; both anterior and posterior vestibules present, the former larger; radial pore canals straight, widened at their bases, widely spaced; normal pore canals scattered, sieve-like; hinge gongylodont; muscle scars comprising 4 adductors and a broadly V-shaped antennal scar, others not observed. Anatomically unknown. Sex dimorphism not noted.



**DIMENSIONS:** Hypotypes, adults, Nat. Mus. Vic. Reg. No. J79: length 0.54 mm, height 0.30 mm, breadth 0.28 mm; length 0.51 mm, height 0.30 mm, breadth 0.28 mm.

**REMARKS:** There seems to be little doubt that the present material is identical with the 'Challenger' specimens described by Brady, but it seems most unlikely that these are identical with the fossil Antwerp Crag species. Since a new name for the Australian forms may well be warranted, the referral above is highly tentative.

**DISTRIBUTION:** South-eastern and eastern Australia, (?) Neogene of Europe.

***Loxoconcha trita* sp. nov.**

(Pl. 11, fig. 10; Fig. 3m)

**DERIVATION OF NAME:** For its general lack of distinguishing characters—*L. tritum* = commonplace.

**MATERIAL:** Seaholme, 5 individuals.

**DIAGNOSIS:** A subrhomboid *Loxoconcha* of medium size, reticulate surface, with flat eye tubercles and a posteroventral ridge, denticulate antero- and posteroventrally. In dorsal view amygdaloidal; greatest breadth medial, slightly less than the height (which is about  $\frac{3}{4}$  the length). Internally: generally similar to *L. australis* but differing in details (lamellae, anterior vestibule, radial pore canals, normal pore canal pattern, etc.). Anatomically unknown. Sex dimorphism not noted.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J80: length 0.55 mm, height 0.33 mm, breadth 0.30 mm; paratypes, adults, Nat. Mus. Vic. Reg. No. J81: length 0.53 mm, height 0.33 mm, breadth 0.29 mm; length 0.54 mm, height 0.31 mm, breadth 0.29 mm.

**TYPE LOCALITY:** Tide pool, Seaholme.

**REMARKS:** Neither the 'Challenger' species nor the New Zealand species described by Hornibrook (*op. cit.* p. 49) resemble this species which is distinguished, paradoxically, by its relatively featureless carapace.

**DISTRIBUTION:** South-eastern Australia.

***Loxoconcha gilli* sp. nov.**

(Pl. 12, fig. 4; Fig. 4k)

**DERIVATION OF NAME:** For Mr E. D. Gill, F.G.S., Assistant Director of the National Museum of Victoria.

**MATERIAL:** Seaholme, 3 individuals.

**DIAGNOSIS:** A *Loxoconcha* species characterized by small size; subquadrate shape in lateral view; inflated ventrally; surface ornamented by reticulations and riblets (as illustrated), reaching a peak posteroventrally from which it falls away posteriorly in 3 uneven steps; eye tubercle weak; shallow dorsomedial sulcus present; dorsal and ventral margins nearly straight, narrowing posteriorly; anterior broadly rounded; posterior subrounded; greatest height anteromedial, about  $\frac{5}{8}$  the length. In dorsal view subhastate; tapered anteriorly, stepped posteriorly; greatest breadth posteromedial, about equal to the height. Internally: generally similar to *L. australis*. Anatomically unknown. Sex dimorphism not observed.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J82: length 0.43 mm, height 0.25 mm, breadth 0.25 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J83: as for holotype.

TYPE LOCALITY: Tide pool, Seaholme.

REMARKS: Easily separated from other species by its unusual surface sculpture.

DISTRIBUTION: South-eastern Australia.

Genus *Loxoconchella* Triebel 1954

*Loxoconchella pulchra* sp. nov.

(Fig. 4c)

DERIVATION OF NAME: *L. pulchra* = beautiful.

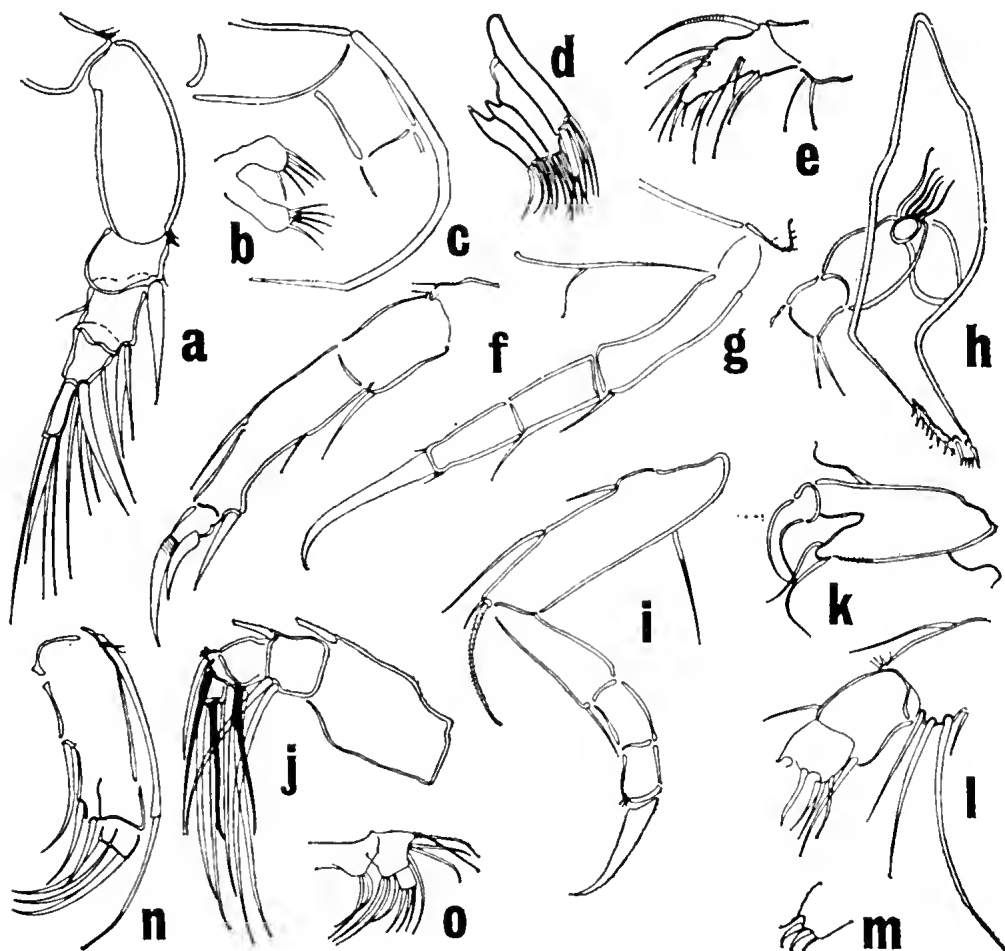


FIG. 7—a-i, *Loxocythere hornibrooki*, ♂ Holotype, NMV J45, × 400. a, 1st antenna. b, Brush-shaped organs. c, 2nd antenna, displaying exopodite. d, Maxilla, palp and lobes. e, Mandible palp. f, Distal 2nd antenna. g, P III. h, Mandible coxale. i, P I. j-m, *Australoecia victoriensis* gen. et sp. nov., ♂ Paratype, NMV J44, × 400. j, 1st antenna, some bristles shaded to avoid confusion of detail. k, Left palp, ♂ 2nd maxilla. l, Part of 2nd antenna. m, Distal furca. n-o, *Parakriothella australis* sp. nov., ♀ Holotype, NMV J50, × 400. n, Distal 2nd antenna and exopodite. o, Mandible palp.

MATERIAL: Ricketts Point, 15 individuals.

DIAGNOSIS: A *Loxoconchella* characterized by medium size; rounded-subrhomboid shape in lateral view; smooth shell, with numerous scattered pits; patches of reddish pigment in some individuals; dorsum gently convex; venter sinuated antero-medially; anterior broadly rounded; posterior obliquely rounded below and inflexed above, ending in a short, truncate, subdorsal process; greatest height posteromedial,  $\frac{3}{4}$  the length. In dorsal view subelliptical; greatest breadth medial, about half the length. Internally: lamellae broad; line of concrescence scalloped, nowhere coincident with the regular inner margin; radial pore canals polyfurcated; normal pore canals numerous, sieve-like; hinge adont; muscle scars comprising 4 adductors and an antennal sear, others not seen. Anatomically not known. Sex dimorphism present, females higher than males.

DIMENSIONS: Holotype, adult ♂, Nat. Mus. Vic. Reg. No. J84: length 0.54 mm, height 0.37 mm, breadth 0.28 mm; paratypes, adult ♂, Nat. Mus. Vic. Reg. No. J85: length 0.53 mm, height 0.37 mm, breadth 0.26 mm; adult ♀ (disarticulated), Nat. Mus. Vic. Reg. No. J85: length 0.53 mm, height 0.40 mm.

TYPE LOCALITY: Swash mark, Ricketts Point.

REMARKS: There are at least two species groups in *Loxoconchella*, the first characterized by a large dorsomedial boss on each valve (*L. anomala* Brady, *L. dorsobullata* Hartmann), the other without this boss. The present material belongs in the second group (together with *L. honoluluensis* Brady, the type species) but differs from *L. honoluluensis* in that it is smaller, more inflexed posterodorsally, and lacks the typical surface patch pattern of that species.

DISTRIBUTION: South-eastern Australia.

Subfamily PARADOXOSTOMATINAE Brady and Norman, 1889

Genus *Paradoxostoma* Fischer 1855

*Paradoxostoma romei* sp. nov.

(Fig. 4c, Fig. 8 i-r)

DERIVATION OF NAME: For Dom Remacle Rome, o.s.b., ostracode neontologist, the Catholic University, Louvain.

MATERIAL: Seaholme, 2 individuals; Ricketts Point, 2 individuals.

DIAGNOSIS: A *Paradoxostoma* of medium size; elongate ovate shape; smooth surface; pallid to pale brownish colour; dorsum gently convex; venter straight; anterior rounded; posterior subacuminate posterodorsally; greatest height slightly less than half the length. In dorsal view subelliptical; greatest breadth medial, about  $\frac{5}{8}$  the height—thus this species is broader (with respect to its height and length) than most others described in the genus. Internally: lamellae broad; inner margin regular; line of concrescence following the outer valve margin; radial pore canals few, very short; normal pore canals few, scattered, simple; hinge lophodont with an anterior antislip ridge in the RV, behind the anterior element, LV complementary; muscle scars comprising 4 adductors and 2 (?) antennal scars, others not seen. Anatomically: 1st antenna long and narrow, 4th joint longer than others (2nd-6th); 2nd antenna with a jointed exopodite, reaching almost to the tips of the terminal endopodite claws, 2nd endopodite joint long and narrow; mandible with a slender coxale and rudimentary palp; maxilla with slender lobes, the innermost with 2 setae, the 2nd and 3rd each bearing 3 setae; 1st leg with a very strong dorsodistal spine

on the 1st joint; legs increasing in length posteriorly; generic status confirmed by the typical suctorial disc of the mouth parts. Sex dimorphism weak.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J86; length 0.65 mm, height 0.31 mm, breadth 0.26 mm; paratype, disarticulated ♀ adult, Nat. Mus. Vic. Reg. No. J87; length 0.69 mm, height 0.30 mm.

**TYPE LOCALITY:** Swash mark, Ricketts Point.

**REMARKS:** Few species of this subfamily have been described from the region (Benson 1964b, 397-405, 414-417) and of these only *P. antarcticum* Müller, 1908, even slightly resembles the present species. The sub-family as a whole is always closely associated with the phytobenthos.

**DISTRIBUTION:** South-eastern Australia.

***Paradoxostoma commune* sp. nov.**

(Fig. 4h)

**DERIVATION OF NAME:** Since it occurs more frequently than any other paradoxostomatid in the collections—*L. communis* = common.

**MATERIAL:** Seaholme, 5 individuals; Ricketts Point, 2 individuals.

**DIAGNOSIS:** A *Paradoxostoma* characterized by medium size; elongate-ovate shape in lateral view; smooth shell; pallid to straw colour; dorsum evenly convex; venter weakly sinuated anteromedially; anterior more narrowly rounded than the posterior; greatest height posteromedial, distinctly less than half the length. In dorsal view narrowly elliptical; ends subacuminate; greatest breadth posteromedial, about  $\frac{2}{3}$  the height. Internally: lamellae broad; line of concrescence and radial pore canals developing a distinctive pattern (as illustrated); normal pore canals scattered, simple; LV hingement without an antislip ridge behind the anterior socket; 4 adductor muscle scars present, other scars not observed. Anatomically unknown. Sex dimorphism not noted.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J88; length 0.51 mm, height 0.23 mm, breadth 0.15 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J89; length 0.49 mm, height 0.20 mm, breadth 0.14 mm.

**TYPE LOCALITY:** Tide pool, Seaholme.

**REMARKS:** This species is closest to *P. fuscum* Müller, but differs from it in the absence of colour-banding and in the internal pattern developed by the line of concrescence and the radial pore canals. *P. ovatum* Brady, has a less elongate shell.

**DISTRIBUTION:** South-eastern Australia.

***Paradoxostoma trapezoideum* sp. nov.**

(Fig. 4i)

**DERIVATION OF NAME:** For its general shape in lateral view.

**MATERIAL:** Seaholme, 3 individuals.

**DIAGNOSIS:** A *Paradoxostoma* of small-medium size; trapezoid shape in lateral view; smooth shell; straw to pale brownish colour; dorsum short and straight; venter weakly sinuated medially; anterior rounded; posterior subacuminate; greatest height medial, much less than half the length. In dorsal view resembling the previous species, *P. communis*, except that the greatest breadth is medial. Internally: lamellae broad; line of concrescence and radial pore canals developing the distinctive pattern illustrated; normal pore canals as in previous species; hinge lophodont, without an

aneillary antislip ridge; muscle scars comprising 6 dorsal scars, in addition to the usual adductor group of 4. Anatomically unknown. Sex dimorphism not noted.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J90: length 0.45 mm, height 0.16 mm, breadth 0.13 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J91: length 0.43 mm, height 0.16 mm, breadth 0.11 mm.

**TYPE LOCALITY:** Tide pool, Seaholme.

**REMARKS:** The shape of this species in lateral view and the internal lamellar pattern are unique.

**DISTRIBUTION:** South-eastern Australia.

Genus *Cytherois* G. W. Müller 1884

*Cytherois dissimilis* sp. nov.

(Fig. 4 l)

**DERIVATION OF NAME:** Because it is distinctly inequivalved—*L. dissimilis* = unlike.

**MATERIAL:** Seaholme, 5 individuals; Ricketts Point, 1 individual.

**DIAGNOSIS:** A species of *Cytherois* of small size; subovate shape; smooth shell; pallid to pale brownish colour; inequivalved, RV higher than LV, overreaching it dorsally; dorsal margins arched (more strongly in RV than LV); venter nearly straight; both ends narrowly rounded in LV; anterior narrowly but posterior broadly rounded in RV; greatest height medial, about half the length (LV) or more than half the length (RV). In dorsal view narrowly ovate; greatest breadth just posteromedial, about  $\frac{2}{3}$  the length. Internally: lamellae broad; anterior and posterior vestibules present; radial pore canals short, widened at their bases; normal pore canals scattered, simple; hinge lophodont; muscle scars comprising 4 adductors, a large antennal scar and 2 mandibulars, dorsal scars not observed. Anatomically unknown. Sex dimorphism not observed.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J92: length 0.41 mm, height 0.19 mm (LV), 0.23 mm (RV), breadth 0.16 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J93: length 0.39 mm, height 0.21 mm, breadth 0.15 mm.

**TYPE LOCALITY:** Tide pool, Seaholme.

**REMARKS:** This species is easily separated on the grounds of shape, lamellar pattern and marked RV overlap from the classic species described by Müller (1894, 1908) and Sars (1928).

**DISTRIBUTION:** South-eastern Australia.

*Cytherois bonaducei* sp. nov.

(Fig. 4m)

**DERIVATION OF NAME:** For Dr G. Bonaduce, Stazione Zoologica, who kindly provided topotypic material of several of the paradoxostomatids from the Bay of Naples described by G. W. Müller in his classic monograph (1894).

**MATERIAL:** Seaholme, 6 individuals.

**DIAGNOSIS:** A *Cytherois* characterized by small size; elongate ovate shape in lateral view; smooth shell; pallid to straw colour; inequivalved, RV slightly higher than LV posteromedially; dorsum evenly convex; venter sinuated anteromedially; anterior more narrowly rounded than the posterior; greatest height posteromedial, about  $\frac{1}{3}$  the length. In dorsal view narrowly ovate; greatest breadth posteromedial at

$\frac{2}{3}$  the length from the front, and equal to slightly less than the height. Internally: lamellae broad; vestibules large; radial pore canals short, widened at their bases; normal pore canals scattered, simple; hinge lophodont; muscle scars as in previous species, additionally 4 dorsal scars were observed. Anatomically unknown. Sex dimorphism not noted.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J94: length 0.44 mm, height 0.14 mm, breadth 0.13 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J95: length 0.39 mm, height 0.13 mm, breadth 0.13 mm.

**TYPE LOCALITY:** Tide pool, Seaholme.

**REMARKS:** This species is generally similar to *C. frequens* Müller, *C. vitrea* Sars and *C. pusilla* Sars, but can be separated on the grounds of slight differences in general shape and in the internal lamellar pattern.

**DISTRIBUTION:** South-eastern Australia.

Genus **Paracytherois** G. W. Müller 1894

**Paracytherois portphillipensis** sp. nov.

(Fig. 4d, g)

**DERIVATION OF NAME:** For the locality, Port Phillip Bay, Victoria.

**MATERIAL:** Seaholme, 3 individuals.

**DIAGNOSIS:** A species of *Paracytherois* of small-medium size; elongate subovate shape; smooth shell; pallid to straw colour; valves subequal; dorsum arched; venter sinuated anteromedially; anterior more narrowly rounded than the posterior; greatest height posteromedial, less than half the length. In dorsal view narrowly ovate; greatest breadth at slightly less than  $\frac{2}{3}$  the length from the front, equalling about  $\frac{3}{4}$  the height. Internally: lamellae broad; anterior vestibule wide and deep, posterior vestibule elongate and narrow; radial pore canals short, widened at their bases; normal pore canals scattered, simple; hinge lophodont; muscle scars comprising 5 adductors in an inclined row trending anteroventrally (characteristic of the genus) and at least 2 dorsal scars, others not observed. Anatomically unknown. Sex dimorphism not noted.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J96: length 0.46 mm, height 0.21 mm, breadth 0.16 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J97: length 0.46 mm, height 0.21 mm, breadth 0.15 mm.

**REMARKS:** The only described species with a closely similar shape is *Paracytherois similis* Müller (an Antarctic form) which is easily distinguished from the present species by its deeply incised ventral line of conerescence.

**TYPE LOCALITY:** Tide pool, Seaholme.

**DISTRIBUTION:** South-eastern Australia.

Subfamily **MICROCYTHERINAE** Klie, 1938

Genus **Microcythere** G. W. Müller 1894

**Microcythere macphersoni** sp. nov.

(Fig. 3h)

**DERIVATION OF NAME:** For Miss H. Macpherson (now Mrs I. Black), Curator of Molluscs, the National Museum of Victoria, when the collections were made.

**MATERIAL:** Seaholme, 13 individuals.

**DIAGNOSIS:** A species of *Microcythere* characterized by small size; narrowly subtriangular shape in lateral view; smooth shell, with a prominent shallow, trans-

verse medial sulcus; pallid to brownish colour; valves sub-equal; dorsum arched; venter gently convex; ends subacuminate; greatest height just posteromedial, approximately equal to the height. Internally: lamellae broad anteriorly and posteriorly, narrow ventrally; anterior and posterior vestibules prominent, subequal; radial pore canals short, widened at their bases, normal pore canals scattered, simple; hinge strongly lophodont; muscle scars comprising 4 adductors, a large heart-shaped antennal scar and 2 mandibulars, dorsal scars not observed. Anatomically unknown. Sex dimorphism marked, females higher and broader than males.

**DIMENSIONS:** Holotype, adult ♀, Nat. Mus. Vic. Reg. No. J98: length 0·33 mm, height 0·18 mm, breadth 0·19 mm; paratypes, Nat. Mus. Vic. Reg. No. J99: adult ♀: length 0·33 mm, height 0·18 mm, breadth 0·18 mm; adult ♂: length 0·31 mm, height 0·15 mm, breadth 0·14 mm.

**TYPE LOCALITY:** Tide pool, Seaholme.

**REMARKS:** The finest series of descriptions of species in this genus is still that of Müller, who named 9 species when first establishing the genus, and subsequently a tenth (Müller 1894, 1908). These and all other described *Microcythere* species differ from the present species in details of general shape, internal lamellar pattern and normal pore canal pattern. Like the Paradoxostomatinae, members of this subfamily also are closely associated with the phytobenthos in sublittoral environments, and further, often occur interstitially in the sediment substrate.

**DISTRIBUTION:** South-eastern Australia.

Subfamily HEMICYTHERINAE Puri, 1953

Genus *Ambostracon* Hazel 1962

'*Ambostracon*' *pumila* (G. S. Brady) 1866

(Pl. 12, fig. 8; Fig. 4b, Fig. 5i)

*Cythere pumila* G. S. Brady, 1866, p. 378, Pl. 60, figs. 7a-d.

**MATERIAL:** Seaholme, 21 individuals; Ricketts Point, 45 individuals.

**DIMENSIONS:** Hypotypes, Nat. Mus. Vic. Reg. No. J100, adult ♀: length 0·67 mm, height 0·38 mm, breadth 0·28 mm; adult ♂: length 0·65 mm, height 0·34 mm, breadth 0·25 mm.

**LOCALITY:** Tide pool, Seaholme.

**REMARKS:** *Ambostracon* species are characterized externally by an ornament of heavy ribs and intermediate reticulations, in contrast to *Mutilus* Neviani, which has a surface ornament of very strong reticulations only, and usually a less elongate carapace. Brady's species (type locality: Australia) differs from the others in surface sculpture and, internally, by the presence of fewer radial pore canals (about 55-65) than *A. costatum* Hazel, the type species *A. glauca* (Skogsberg) and *A. diegoensis* (LeRoy), all of which have about 75-100. A difference in the number of radial pore canals has already been used as a diagnostic character at generic level in the Hemicytherinae, viz., *Pokornyella* Oertli. Since some South African forms are similar to '*A.*' *pumila* in this respect further research may lead to the designation of a new generic or subgeneric category. The subfamily has been poorly represented in the Recent Australian marine faunules which I have examined so far, e.g., out of more than 200 species from Sahul Shelf only about 5 are Hemicytherinids; in the present faunule of about 50 species only one is a Hemicytherinid. This contrasts with an abundance of species off California and South Africa.

**DISTRIBUTION:** South-eastern Australia.

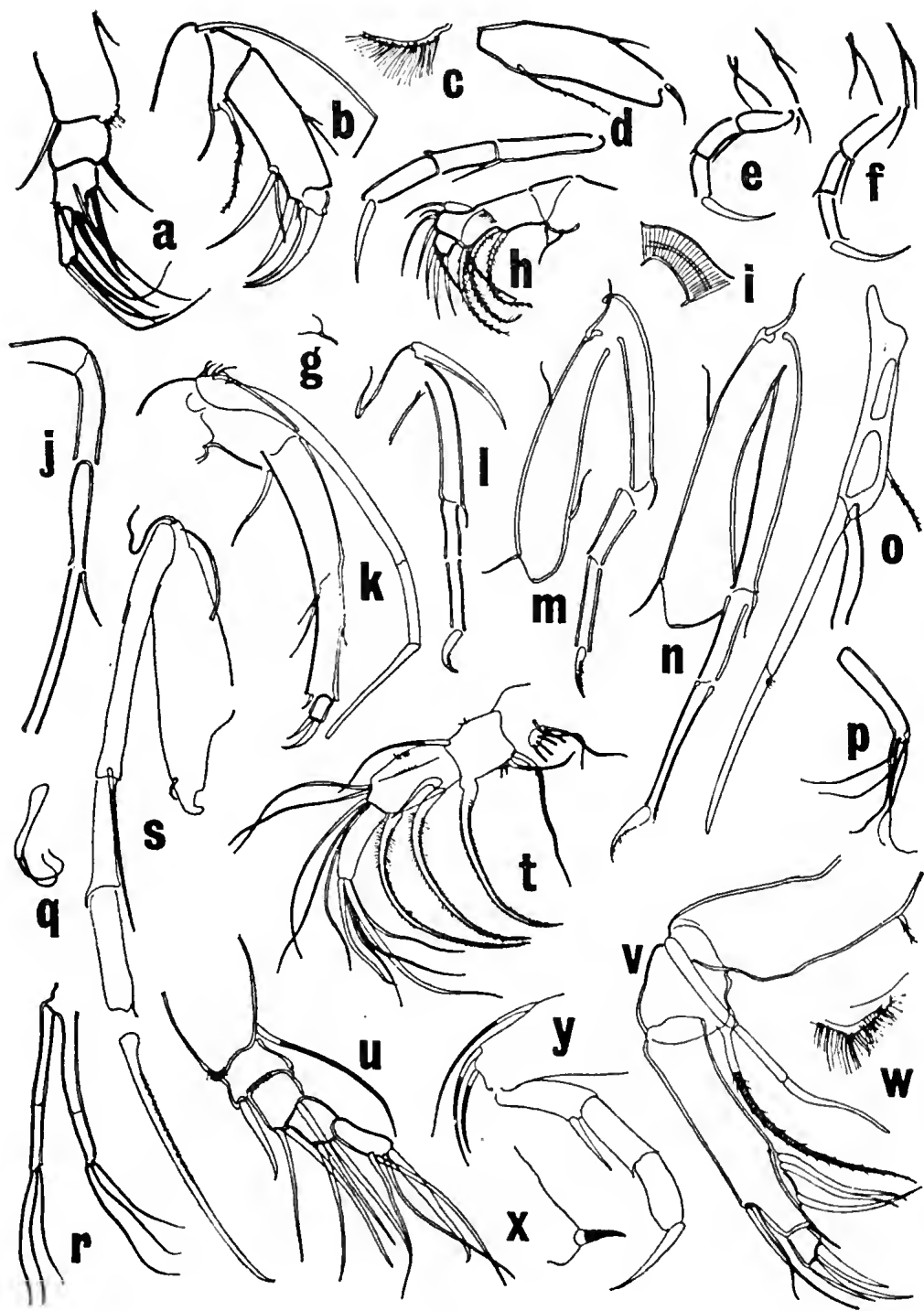


FIG. 8 →



## Subfamily TRACHYLEBERIDINAE Sylvester-Bradley, 1948

Genus *Cletocythereis* Swain 1963*Cletocythereis* cf. *rastromarginata* Brady 1880

(Pl. 13, figs. 1-2; Fig. 6b, Fig. 10a-b)

*Cythere rastromarginata* Brady, 1880, p. 83, Pl. 16, figs. 1a-d (figs. 2a-d not *rastromarginata*).  
*Bradleya rastromarginata* (Brady); Hornibrook, 1952, p. 17.

MATERIAL: Ricketts Point, 5 individuals.

DIMENSIONS: Hypotypes, Nat. Mus. Vic. Reg. No. J101, adult ♂: length 0.80 mm, height 0.38 mm, breadth 0.25 mm; adult ♀: length 0.75 mm, height 0.38 mm, breadth 0.24 mm.

LOCALITY: Swash mark, Ricketts Point.

REMARKS: *Cletocythereis* species are characterized by the development in the LV of a prominent anterodorsal rim-tooth which protrudes over the RV margin, in addition to the normal amphidont hinge elements. This is an unusual feature in trachyleberidids, found only in *Idiocythere* and an as yet undescribed genus (*Cythere cristatella* Brady from Sahul Shelf) apart from its occurrence in *Cletocythereis*. These three categories can be separated on the presence or absence of an eye tubercle, type of surface ornamentation, width of inner lamellae, type and grouping of radial pore canals, details of the hinge and breadth of carapace. Further, *Idiocythere* is an exclusively fossil genus, ranging from the Upper Cretaceous to the Eocene (Triebel personal communication). *Cletocythereis*, however, apparently ranges from the Eocene-Recent (Hornibrook 1952, p. 19), while the category represented by *Cythere cristatella* Brady is probably restricted to the Neogene.*C. rastromarginata* (the type species of *Cletocythereis*) was collected by the 'Challenger' off Honolulu, off East Moncoeur Island, and at Station 167 in New Zealand waters, but the latter record (notwithstanding Brady's comments) is evidently a different species. The genus is restricted to tropical and warm temperate waters in the Pacific, Indo-Pacific and Australasian regions so that *C. nobilissimus* Swain, which is Boreal, should be referred to another category.

DISTRIBUTION: Honolulu (?), South-eastern Australia.

*Cletocythereis curta* sp. nov.

(Fig. 5g, Fig. 6a)

DERIVATION OF NAME: For the relatively short carapace—*L. curta* = shortened.

MATERIAL: Seaholme, 3 individuals.

DIAGNOSIS: A *Cletocythereis* closely similar in appearance to the previous species but with a shorter heavier shell (less length/height ratio); also reticulate, but with the ridges of the reticulations wider so that the pits are uniformly smaller than in the previous species; the dorsal ridge more prominent at its posterodorsal corner in this species. Internally: without an anterior vestibule and with fewer,

FIG. 8—a-h, *Callistocythere hartmanni* sp. nov., ♀ Holotype, NMV J72, × 400. a, 1st antenna, some bristles shaded to avoid confusion of detail. b, 2nd antenna. c, Lower lip. d, P III. e, P I. f, P II. g, Spine, posterior of body. h, Mandible palp. i-r, *Paradoxostoma romei* sp. nov., ♀ Paratype, NMV J87, × 400. i, Suctorial disc. j, Part of 1st antenna. k, 2nd antenna. l, P I. m, P II. n, P III. o, Mandible coxale. p, Mandible palp. q, Maxilla 1st lobe. r, Maxilla 2nd and 3rd lobes. s-y, '*Doratocythere venata* (Brady), ♀ Hypotype, NMV J109, × 400. s, P III. t, Mandible palp. u, 1st antenna. v, 2nd antenna. w, Lower lip. x, Spine, posterior of body. y, P I.

longer anterior radial pore canals; antennal muscle scar divided. Anatomically unknown. Sex dimorphism not as marked as in the previous species.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J102: length 0.63 mm, height 0.35 mm, breadth 0.23 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J103: length 0.64 mm, height 0.34 mm, breadth 0.23 mm.

**TYPE LOCALITY:** Tide pool, Seaholme.

**REMARKS:** Although similar in many respects, in others this species differs consistently from the type species and warrants separate status. As far as I am aware it is shorter than any other species in the genus.

**DISTRIBUTION:** South-eastern Australia.

### Genus *Ponticocythereis* gen. nov.

**DERIVATION OF NAME:** For Dr J. E. Hazel, United States Geological Survey, who has long recognized the distinctness of this category—Gk *ponticos* = hazel, and generic name *Cythereis*.

**TYPE SPECIES:** *Ponticocythereis militaris* (Brady), 1866.

**DIAGNOSIS:** A trachyleberidinid genus with a strong subquadrate carapace; ornamented by numerous coarse pointed or blade-like spines which project, continuously or discontinuously, around the entire margin of each valve and along a more or less distinct median ridge, the intervening areas perfectly smooth; eye tubercle large, round, glassy; subcentral tubercle present, sometimes obscured by the median ridge; height about half the length; selvage prominent; inner lamellae moderately broad; vestibules absent; radial pore canals tending to group; hinge holamphidont; antennal scar V-shaped; anatomically imperfectly known; distal joint of the 1st antenna elongate; endopodite joints of the 2nd antenna stouter than in *Cletocythereis*; unfortunately, nothing is known about the structure of the three paired posterior leg-like limbs, but there is a weak asymmetry in the valves which suggests that the left and right limbs of one or more of these pairs may also be asymmetrical. Asymmetry of one or more of the paired posterior limbs in trachyleberidinids has already been observed for several genera including *Trachyleberis* Brady, *Actinocythereis* Puri, *Costa* Neviani, *Buntonia* Howe and *Occultocythereis* Howe (Harding & Sylvester-Bradley 1953, p. 10; Müller 1894, Pl. 31; Hazel, personal communication).

**REMARKS:** This genus is closest to *Trachyleberis*, *Costa* and *Actinocythereis* in general shape, although there is little possibility of confusion with *Trachyleberis* which has a subaeuminate posterior. Further its pattern of surface ornament (which is consistent in all known species) suffices to distinguish it from *Trachyleberis* which is spiny over the entire surface. In *Costa* the median ridge ends in a dog-leg posteriorly, and the intervening areas are often reticulate. *Actinocythereis* is higher with respect to its length, has a thicker shell, and is often ornamented with numerous tubercles. Internally: all are rather similar, except that in the present genus radial pore canals show a tendency to group (as illustrated).

**DISTRIBUTION:** Pacific, Indo-Pacific, Australasia.

**AGE:** Tertiary to Recent.

### *Ponticocythereis militaris* Brady 1866

(Pl. 13, fig. 4; Fig. 4 o, Fig. 10 c-d)

*Cythereis militaris* Brady, 1866, p. 385, Pl. 61, figs. 9a-d.

*Cythere clavigera* Brady, 1880, p. 109, Pl. 23, figs. 7a-d.

*Cythere militaris* Brady: Brady, 1890, p. 504, Pl. 2, figs. 24-26 (not *militaris*).

*Trachyleberis clavigera* (Brady); Hornibrook, 1952, p. 15.

*Tracyleberis militaris* (Brady); McKenzie, 1964, pp. 448-543 (not *militaris*).

MATERIAL: Seaholme, 6 individuals.

DIMENSIONS: Hypotypes, Nat. Mus. Vic. Reg. No. J104, adult ♂: length 1.00 mm, height 0.50 mm, breadth 0.43 mm; adult ♀ (LV): length 0.85 mm, height 0.48 mm.

REMARKS: Diagnostic characters for species in this genus include variations in the type and groupings of spines, particularly along the dorsal margin and the medial longitudinal ridge. Such variations suffice to distinguish *P. militaris* from the other described species *P. ichthyoderma* and *P. quadriserialis* (Brady 1890, p. 503, Pl. 2, figs. 22, 23 and p. 504, Pl. 2, figs. 27, 28). The form described and illustrated by Brady, 1890, as an adult female *C. militaris*, from specimens dredged at Princess Royal Harbour, near Albany, Western Australia (Brady *op. cit.*) is not *P. militaris* but another, unnamed, species which bears pointed spines dorsally rather than flattened bladelike spines as in *P. militaris*. On the other hand, *C. clavigera* Brady, collected by the 'Challenger' at Port Jackson, is identical with *C. militaris* (type locality: Hobsons Bay) as foreshadowed by Brady in his comments (Brady 1880, p. 110).

DISTRIBUTION: South-eastern Australia.

#### Subfamily XESTOLEBERIDINAE Sars, 1928

##### Genus *Xestoleberis* Sars 1866

##### *Xestoleberis tigrina* (Brady) 1866

(Fig. 4a, Fig. 10e-n)

*Cytherideis tigrina* Brady, 1866, p. 369, Pl. 58, figs. 5a-d.

MATERIAL: Seaholme, 23 individuals; Ricketts Point, 52 individuals.

DIMENSIONS: Hypotypes, Nat. Mus. Vic. Reg. No. J105, adult ♂: length 0.65 mm, height 0.36 mm, breadth 0.33 mm; adult ♀: length 0.63 mm, breadth 0.39 mm.

LOCALITY: Swash mark, Ricketts Point.

REMARKS: Direct comparison against Brady's types has shown that the present material is undoubtedly his species which was collected from 'Australia (littoral shell-sand Melbourne)'.

DISTRIBUTION: South-eastern Australia.

##### *Xestoleberis briggsi* sp. nov.

(Fig. 4n)

DERIVATION OF NAME: For W. Briggs, Jr., presently working on Neogene ostracodes of New Zealand.

MATERIAL: Seaholme, 4 individuals; Ricketts Point, 2 individuals.

DIAGNOSIS: A species of *Xestoleberis* characterized by small-medium size; narrowly ovate shape in lateral view; smooth surface; dorsal margin arched; ventral margin nearly straight; anterior narrowly rounded; posterior broadly rounded; eye scar present; greatest height approximately medial, about half the length. In dorsal view subovate; anterior tapered; posterior broadly rounded; greatest breadth posteromedial, little more than the height. Internally: lamellae broadest anteriorly;

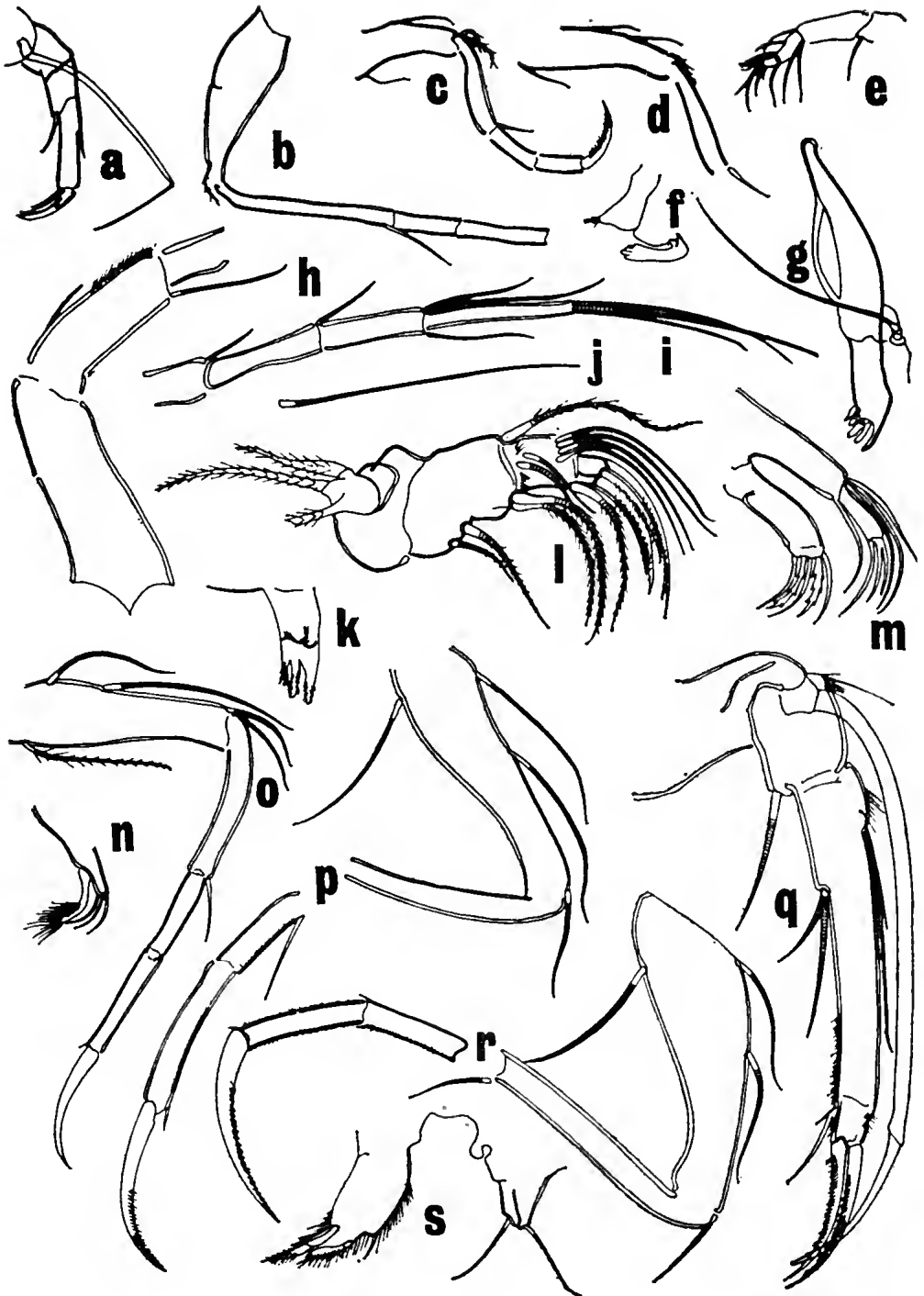


FIG. 9 →

anterior vestibule prominent; radial pore canals simple, usually straight, most numerous anteroventrally; normal pore canals scattered, sieve-like; hinge merodont, LV with crenulate terminal sockets and an intervening crenulate bar, RV complementary; muscle scars large comprising 4 adductors, and a heart-shaped antennal scar, others not observed. Anatomically not known. Sex dimorphism present, females broader than males.

**DIMENSIONS:** Holotype, adult, Nat. Mus. Vic. Reg. No. J106: length 0.43 mm, height 0.21 mm, breadth 0.24 mm.

**TYPE LOCALITY:** Tide pool, Seaholme.

**REMARKS:** This species is smaller than, and generally dissimilar to the previous species, and also to *X. granulosa* Brady, 1880, which was taken off East Monocoeur Island, Bass Strait, and in Port Jackson. Some Noumea material, referred by Brady to *X. granulosa*, also differs from this species in shape and internal features (Noumea types examined).

**DISTRIBUTION:** South-eastern Australia.

#### Subfamily CAMPYLOCYTHERIDINAE Puri, 1960

##### Genus *Doratocythere* gen. nov.

**DERIVATION OF NAME:** For its hastate shape in dorsal view—Gk doru = a spear, and generic name *Cythere*.

**TYPE SPECIES:** *Doratocythere foveata* sp. nov.

**DIAGNOSIS:** A campylocytherinid genus characterized by medium-large size; elongate-subquadrate shape; ornament of scattered pits or reticulations; LV larger than RV; margins usually denticulate antero- and posteroventrally; height less than half the length; weak subcentral tubercule present; in dorsal view, outline of the valves is abruptly truncate at the rear (like a spearhead); inner lamellae broad anteriorly and posteriorly, narrower ventrally; adults without vestibules; radial pore canals moderately numerous (about 50 in all) long, wavy, often thickened, usually unbranched; normal pore canals simple; hinge amphidont, RV with a relatively weak stepped anterior tooth, crenulate median furrow and lobate posterior tooth; shell wall thickened behind and below the anterior hinge elements; observed muscle scars comprise 4 adductors, a V-shaped or U-shaped antennal scar, and one or two mandibulars; between the adductors and the antennal scar is a small, sub-circular micropunctate area. Anatomically: distal (6th) joint of the 1st antenna elongate; lower lip hirsute; 2nd antenna with a well developed 3-jointed exopodite, in females reaching the distal 2nd endopodite joint, slightly longer in males (reaching the distal 3rd endopodite joint), male 2nd antenna endopodite more slender than the female 2nd antenna endopodite, terminal claws short and strong; mandible with an elongate distal joint on the palp, penultimate joint with 3 long feathered ventral bristles; epipodite with 2 long setae and a short seta; epipodial appendage of the maxilla with about 10 Strahlen; legs increasing in length towards the rear, chitin

FIG. 9—a-g, *Cytherura taylori* sp. nov., ♀ Paratype, NMV J53, × 400. a, 2nd antenna. b, P III (claw lost). c, P I. d, P II (proximal joints). e, Mandible palp. f, Rear of body. g, Mandible coxale and epipodial bristle. h-s, *Loxoconcha australis*, ♀ Hypotype NMV J77, × 400. h, Proximal 1st antenna. i, Distal 1st antenna. j, Longest distal bristle of 1st antenna. k, Lower mandible coxale. l, Mandible palp. m, Maxilla palp and 3rd lobe, displaying Zahnborsten. n, Maxilla, 1st lobe and brush-like process. o, P I. p, P II. q, 2nd antenna. r, P III. s, Rear of body (disoriented).

supports simple; female body ending in a short annulate bristle; penis with a broadly triangular anterobasal part.

REMARKS: The thickened shell wall behind the anterior hinge elements is considered to be a diagnostic feature which relates this to other campylocytherinid genera such as *Tringylmus* Blake, *Campylocythere* Edwards and *Acuticythereis* Edwards. The anatomy shows several relationships to the Trachyleberidinac (as defined by Hartmann 1963, p. 138) supporting Puri's assessment on palaeontological grounds of the similarities between the two groups (Puri 1960). In many trachyleberidinid genera, however, the exopodite of the 2nd antenna is markedly different in length in the different sexes, and the penis structure of males also differs from that in *Doratocythere*. The trachyleberidinid genus closest to *Doratocythere* is *Moosella* Hartmann. Apart from a different penis structure, however, *Moosella* differs palaeontologically from the present genus in that: the inner lamellae are narrower, there is a less marked thickening of the shell wall behind the hinge, and there is no micro-punctate area between the adductors and the antennal scar. Width of the inner lamellae, lack of vestibules, and the micropunctate interscar area are sufficient to distinguish *Doratocythere* from the other campylocytherinids mentioned above.

DISTRIBUTION: Southern Australia, from Oyster Harbour, near Albany, Western Australia, to Port Phillip Bay, Victoria (for the known Recent species).

AGE: Neogene to Recent.

***Doratocythere foveata* sp. nov.**

(Pl. 13, fig. 3; Fig. 5a-b)

DERIVATION OF NAME: For the pitted surface—*L. fovea* = a pit.

MATERIAL: Scaholme, 7 individuals.

DIAGNOSIS: A *Doratocythere* characterized by medium-large size, elongate subquadrate shape in lateral view; weakly denticulate anteroventrally, not noticeably so posteroventrally; surface somewhat irregular, truncated posteriorly and ornamented by scattered small deep pits; LV larger than RV, overlapping it dorsally and posterodorsally, posterodorsal margin of LV straight, not inflexed as in RV; dorsal margin sloping backwards; ventral margin sinuated anteromedially; anterior broadly rounded; posterior rounded (LV) or subcaudate (RV); greatest height antero-medial, much less than half the length. In dorsal view subhastate; lateral outlines of the valves slightly depressed behind the subcentral tubercule; valves asymmetrical; greatest breadth less than the height. Internally: lamellae broad; vestibules absent; radial pore canals as in the generic diagnosis; selvage distinct; flange present; normal pore canals scattered, simple, small in diameter; RV hinge consisting of stepped anterior tooth, crenulate median furrow and trilobate posterior tooth, LV complementary; shell wall thickened behind and below the anterior hinge elements; muscle scars comprising 4 adductors, an U-shaped antennal scar and 2 mandibulars; micropunctate interscar area present. Anatomically not known. Sex dimorphism not observed.

DIMENSIONS: Holotype, adult, Nat. Mus. Vic. Reg. No. J107: length 0.88 mm, height 0.38 mm, breadth 0.34 mm; paratype, adult, Nat. Mus. Vic. Reg. No. J108: length 0.86 mm, height 0.35 mm, breadth 0.33 mm.

TYPE LOCALITY: Tide pool, Scaholme.

REMARKS: The surface ornamentation suffices to distinguish this from the following species and from an undescribed species which also occurs in Port Phillip Bay. It closely resembles another undescribed species from King George Sound, near Albany, Western Australia, which however, is less high and has a much wider posteroventral shelf (0.09 mm against 0.04 mm), a different normal pore canal distribution and wider inner lamellae, especially posteroventrally.

**'Doratocythere' venata (Brady) 1866**

(Pl. 12, fig. 9; Fig. 5f, h, Fig. 8s-y)

*Cythere venata* Brady, 1866, p. 374, Pl. 59, figs. 8a-c.

MATERIAL: Seaholme, 21 individuals; Ricketts Point, 3 individuals.

DIMENSIONS: Hypotypes (?), 1st stage ♀, Nat. Mus. Vic. Reg. No. J109: length 0.70 mm, height (LV) 0.34 mm, (RV) 0.31 mm, breadth 0.31 mm.

REMARKS: In the writer's opinion all the specimens of this form which were collected at the two localities on which this paper is based are 1st and 2nd stage juveniles (i.e. in the final moult stages before adulthood). Brady's type material is a juvenile in the 2nd stage removed from adulthood. It is just possible in the writer's opinion, that *Doratocythere foveata* is the adult of '*Doratocythere venata*' but van den Bold considers them to be separate species for the following good reasons: the inner lamellae in '*D. venata*' are unusually wide if the specimens are juveniles, and a vestibule is present; the transverse anterior ridge/furrow of '*D. venata*' does not occur in *D. foveata*; '*D. venata*' has star-shaped normal pore canals, unlike *D. foveata*; the muscle scars have a different orientation in the two forms (van den Bold personal communication). The writer's original reasons for considering the two forms to be one and the same species were: the size difference was about right for *D. foveata* to be the adult of '*D. venata*'; there were no other 'juveniles' resembling *D. foveata* in the collections (nor have any since been found in a rapid look through about 50 samples from Port Phillip Bay), '*D. venata*' appears to have a juvenile hinge (merodont) for a camplocytherinid. However, Professor van den Bold's comments particularly on the muscle scar orientation and normal pore canals, are unanswerable. Brady's species is placed in *Doratocythere sensu lato*, because, although it is similar in general shape and has a micropunctate interscar area, the differences in lamellae, normal pore canals and hingement place it outside *Dorotocythere, sensu stricto*.

DISTRIBUTION: South-eastern Australia.

**Campylocytherinid sp.**

(Pl. 12, fig. 7; Fig. 5d)

MATERIAL: Seaholme, 4 individuals.

DIAGNOSIS: A campylocytherinid of medium-large size, subquadrate shape in lateral view; ornament of weak reticulations, with each reticule microreticulate; a shallow transverse anterior furrow; subcentral tubercle present; margins denticulate antero- and posteroventrally; greatest height anteromedial, about half the length. In dorsal view broadly elliptical; narrower anteriorly than posteriorly; greatest breadth approximately medial, about equalling the height. Internally: lamellae broad, RV of specimen (opened) with vestibules (as illustrated), LV without vestibules; radial pore canals (LV) long, wavy; normal pore canals scattered, simple; hinge merodont with a crenulate median element; shell wall slightly thickened behind the anterior hinge elements; muscle scars comprising 4 adductors, a V-shaped antennal scar,



FIG. 10      —————>



single mandibular and 2 other smaller sears. Anatomically unknown. Sex dimorphism weak, females broader than males.

DIMENSIONS: Nat. Mus. Vie. Reg. No. J110: 1st stage juvenile, ♀, length 0.75 mm, height 0.38 mm, breadth 0.40 mm; 1st stage juvenile, ♂: length 0.74 mm, height 0.36 mm, breadth 0.33 mm.

REMARKS: This species of which only juveniles were collected (2, 1st stage and 2, 2nd stage) is placed in the Campylocytheridinae on the basis of the slightly thickened shell wall behind the anterior hinge elements, but may be a trachyleberidinid. The weak hinge, immature inner lamellae and poorly developed surface ornamentation all suggest that the specimens are juveniles, and a more critical appraisal of their status must await the finding of adult individuals (which would measure about 1mm).

DISTRIBUTION: South-eastern Australia.

### Undescribed Species

In addition to those described above several other species occurred in the collections, in each case represented by single specimens only. These have been housed at the National Museum of Victoria as undescribed species (Seaholme: Reg. No. J111; Ricketts Point: Reg. No. J112). The Seaholme species are *Paradoxostoma* sp., *Paracytherois* sp., ? *Luvula* sp., *Hemicytherura* sp., and an undetermined cytherinid. At Ricketts Point were found *Leptocythere* sp., '*Aurila*' sp., *Doratocythere* sp., and an undetermined trachyleberidinid.

### Conclusions

In all, 408 individuals were picked from the Seaholme collection and 276 from Ricketts Point material. These numbers represented a total (including 'undescribed species') of 57 species, of which 33 were present at Ricketts Point and 47 in the Seaholme faunule. Including 'undescribed species', 10 species were exclusive to Ricketts Point and 24 to Seaholme.

The number of specimens picked from each collection is adequate to interpret the assemblage at each locality (Kornicker 1964, p. 49 and Fig. 3). It is evident that the subfamilies Bairdiinae, Cytherellinae, Paraeypridinae, Hemicytheridinae, Xestoleberidinae and the genus *Loxoconchella* characterize the Ricketts Point assemblage, while the subfamilies Cytherurinae, Leptocytherinae, Paradoxostomatinae, Microcytherinae, Campyloeytheridinae and the genus *Pontocythereis* typify the assemblage at Seaholme. Common at both localities are the subfamilies Pontocypridinae (minus *Propontocypris*), Cytherinae, Cytherideinae, Krithinae and *Loxoconchinae* (minus *Loxoconchella*).

The commonest species are *Loxoconcha australis*, *Callistocythere puri*, '*Ambostracon*' *pumila* and *Xestoleberis tigrina*. Characteristic littoral tide pool species include *Cytherura taylori*, *Microcytherura australis*, *Hemicytherura seaholmensis*, *Leptocythere vellicata*, *Hemicytheridea portjacksonensis*, *Microcythere macphersoni*, '*Doratocythere*' *venata*. Characteristic sublittoral species are *Bairdia* sp., *Cytherelloidea keiji*, *Paracypris bradyi*, *Loxoconchella pulchra*. In addition, some

FIG. 10—a-b, *Cletocythereis* cf. *rastrumarginata* (Brady), ♂ Hypotype, NMV J101, × 400. a, 1st antenna. b, 2nd antenna. c-d, *Pontocythereis militaris* (Brady), gen. nov., ♀ Hypotype, NMV J104, × 400. c, 1st antenna. d, 2nd antenna endopodite. e-n, *Xestoleberis tigrina* (Brady), ♀ Hypotype, NMV J105, × 400. e, Mandible coxale. f, Mandible epipodite. g, 1st antenna. h, Mandible palp. i, Lower lip. j, 2nd antenna. k, P II. l, P III. m, P I. n, Maxilla, proximal palp and lobes.

less common species are characteristic of the environment as a whole, e.g., *Loxocythere hornibrooki*, *Australocythereidea vandenboldi*, *Parakrithella australis* and *Ponticocythereis militaris*.

Although 57 species may seem to be an adequate ostracode faunule for this protected environment a cursory glance through samples collected by the National Museum of Victoria in its Port Phillip Bay survey has revealed many species not considered here. It is my hope to study these later.

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### Explanation of Plates

#### PLATE 11

All magnifications  $\times 95$  approximately

- FIG. 1—*Cytherelloidea keiji* sp. nov. Adult ♀, paratype, NMV J35. External lateral view, LV.
- FIG. 2—*Loxocythere hornibrooki* sp. nov. Adult ♀, holotype, NMV J45. External lateral view, LV.
- FIG. 3—*Cytherura taylori* sp. nov. Adult ♀, paratype, NMV J53. External lateral view, LV.
- FIG. 4—*Semicytherura cryptifera* (Brady), 1880. Adult, hypotype, NMV J54. External lateral view, RV.
- FIG. 5—*Semicytherura* sp. Adult, NMV J55. External lateral view, LV.
- FIG. 6—*Semicytherura angusta* sp. nov. Adult, holotype, NMV J58. External lateral view, LV.
- FIG. 7—*Semicytherura tenuireticulata* sp. nov. Adult, paratype, NMV J57. External lateral view, LV.
- FIG. 8—*Hemicytherura seaholmensis* sp. nov. Adult, paratype, NMV J63. External lateral view, RV.
- FIG. 9—*Loxoconcha* sp. Adult, NMV J78. External lateral view, RV.
- FIG. 10—*Loxoconcha trita* sp. nov. Adult, holotype, NMV J80. External lateral view, LV.
- FIG. 11—*Microcytherura australis* sp. nov. Adult, holotype, NMV J64. External lateral view, LV.
- FIG. 12—*Microcytherura gawemuelleri* sp. nov. Adult, paratype, NMV J67. External lateral view, RV.
- FIG. 13—*Australocytheridea vandenboldi* gen. et sp. nov. Adult ♂, holotype, NMV J47. External lateral view, LV.

#### PLATE 12

All magnifications  $\times 95$  approximately

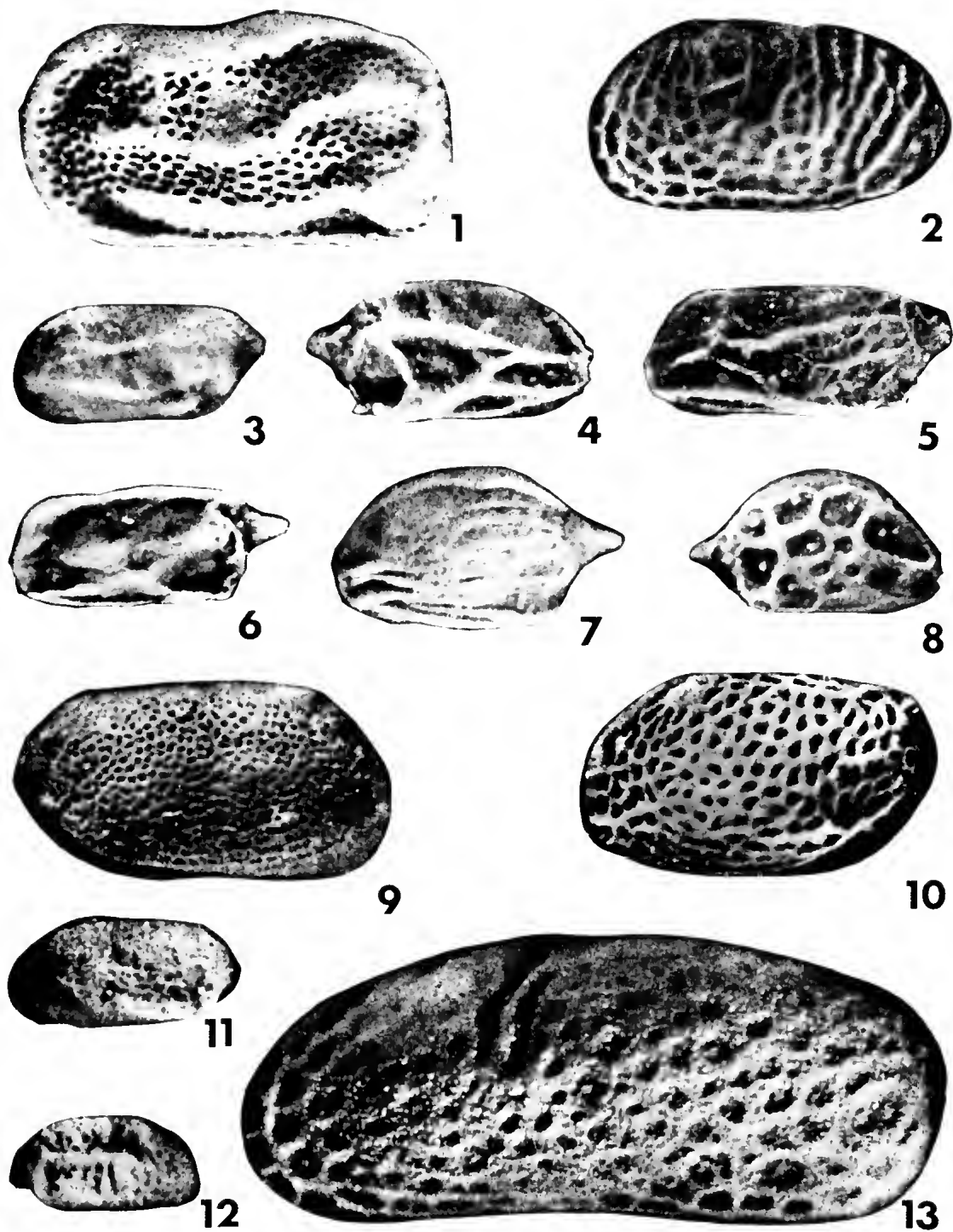
- FIG. 1—*Callistocythere insolita* sp. nov. Adult, holotype, NMV J74. External lateral view, LV.
- FIG. 2—*Callistocythere puri* sp. nov. Adult, hypotype, NMV J71. External lateral view, LV.
- FIG. 3—*Loxoconcha* cf. *variolata* Brady, 1878. Adult, hypotype, NMV J79. External lateral view, LV.
- FIG. 4—*Loxoconcha gilli* sp. nov. Adult, paratype, NMV J88. External lateral view, LV.
- FIG. 5—*Callistocythere hartmanni* sp. nov. Adult ♀, holotype, NMV J72. External lateral view, RV.
- FIG. 6—*'Hemicytheridea' portjacksonensis* sp. nov. Adult ♀, hypotype, NMV J76. External lateral view, LV.

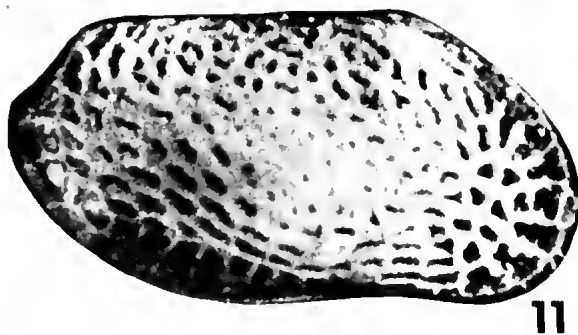
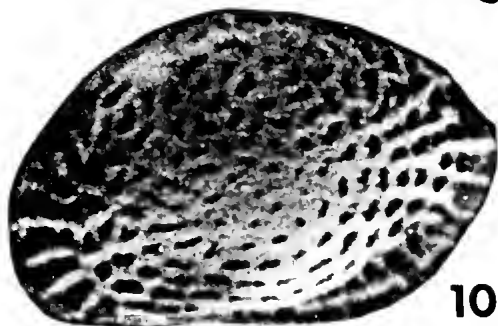
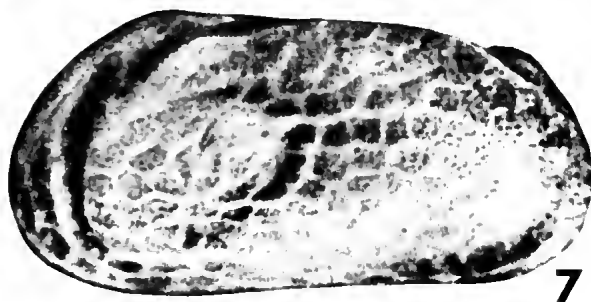
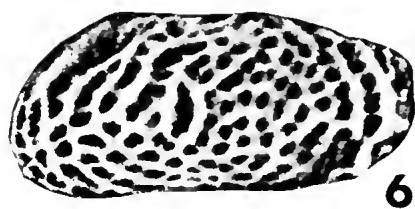
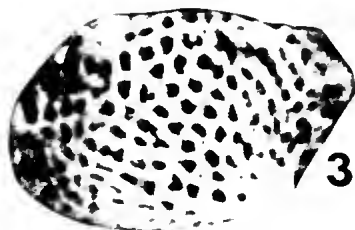
- FIG. 7—*Campylocytherinid* sp. Adult, NMV J110. External lateral view, LV.  
FIG. 8—'*Ambostracon*' *pumila* (Brady), 1866. Adult ♀, hypotype, NMV J100. External lateral view, RV.  
FIG. 9—'*Doratocythere*' *venata* (Brady), 1866. Adult ♀, hypotype, NMV J109. External lateral view, LV.  
FIGS. 10-11—*Loxoconcha australis* Brady, 1880. Hypotypes, NMV J77. Fig. 10: adult ♀, external lateral view, LV. Fig. 11: adult ♂, external lateral view, RV.

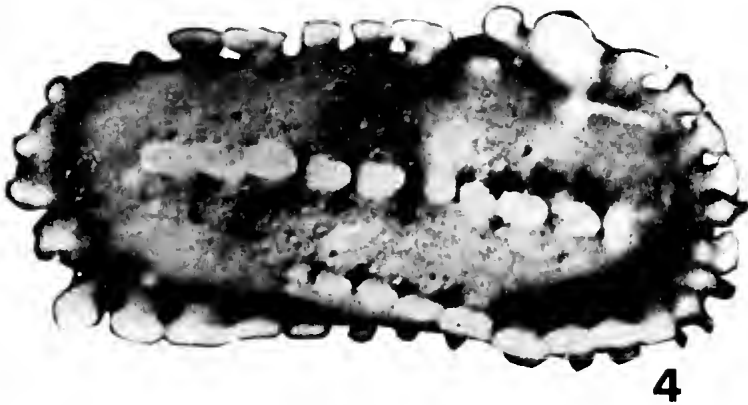
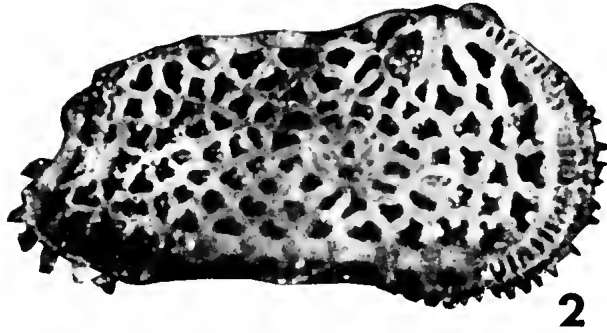
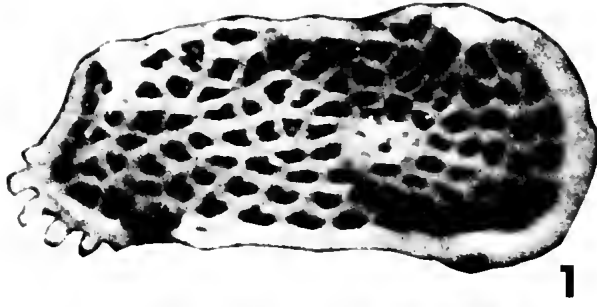
## PLATE 13

All magnifications, except Fig. 2,  $\times 95$  approximately

- FIGS. 1-2—*Cletocythereis* cf. *rastrmarginata* (Brady), 1880. Hypotypes, NMV J101. Fig. 1: adult ♂, external lateral view, RV. Fig. 2: adult ♀, external lateral view, RV, enlarged to same size as male to show sex dimorphism.  
FIG. 3—*Doratocythere foveata* gen. et sp. nov. Adult holotype, NMV J107. External lateral view, RV.  
FIG. 4—*Ponticocythereis* gen. nov. *militaris* (Brady), 1866. Adult ♂, hypotype, NMV J104. External lateral view, RV.











# LOWER DEVONIAN STREPTELASMATID, LINDSTROEMIID AND POSSIBLE AMPLEXOCARINIID CORALS FROM VICTORIA

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## Abstract

Four new genera and eight new, or newly combined species are described and figured, their systematics and distribution being as follows:

### Family STREPTELASMATIDAE

*Streptelasma* (?) *vagens* sp. nov., late Gedinnian or Siegenian, Loyola, Vict.

### Family LINDSTROEMIIDAE

*Haptophyllum erisma* (Hill) gen. nov., Emsian, Buchan, Vict.

*Taralasma radiatum* (Hill) gen. nov., Emsian, Buchan, Vict.

*Tanjilasma meridionale* (Philip) gen. nov., late Gedinnian or Siegenian, Tyers R., Vict.

*Metriophyllum devexicarinatum* sp. nov., late Gedinnian or Siegenian, Tyers R., Vict.

*M. solidum solidum* sp. et subsp. nov., Emsian, Buchan, Vict.

*M. solidum murrindalense* sp. et subsp. nov., Emsian, Buchan, Vict.

*Boolelasma pycnotheca* gen. et sp. nov., late Gedinnian or Siegenian, Tyers R., Vict.

### Family AMPLEXOCARINIIDAE

*Amplexocarinia* (?) *fistella* sp. nov., late Gedinnian or Siegenian, Loyola, Vict.

## Introduction

The generally small and even minute size of the corals described in this paper denies them the opportunity of ever becoming conspicuous elements in the faunas of which they are part. In spite of this, much variation is displayed in their morphology and considerable interest is attached to their study.

In the past, the exceptionally long geological range of the genera with which the species were normally associated, especially, for example, *Metriophyllum*, inevitably had a diminishing effect on their importance as index fossils. But the discovery, in the Lower Devonian of Victoria, of four new genera, unknown in the Upper Silurian and Middle Devonian, suggests that some of these corals may yet play a role in the elucidation of Australian Devonian correlations.

Sincere gratitude is extended to Professor D. Hill, of the University of Queensland, for access to her library and coral collections; to Professor Philip, of the University of New England, for unpublished information concerning correlations by conodonts, and to Mr N. Petrasz, also of the University of New England, for assistance in the preparation of thin sections. The author alone, however, accepts responsibility for their orientation and final thickness. Costs incurred by field-work in Victoria have been born by the University of New England's Research Grant No. 120.

## Systematic Descriptions

The material described in this paper is registered in three institutions, which are subsequently abbreviated as follows:

GSV Geological Survey of Victoria, Melbourne  
 UM University of Melbourne  
 UNE University of New England, Armidale.

Family STREPTELASMATIDAE Nicholson

1889 STREPTELASIMIDAE Nicholson in Nicholson and Lydekker, p. 297.  
 1922 STREPTELASMAIDAE Grabau (emend.), Grabau, p. 28 (incorrect emendation).  
 1927 STREPTELASMATIDAE Wedekind, p. 15.

Genus *Streptelasma* Hall

1847 *Streptoplasma* Hall, p. 17, 49, 69-71 (*lapsus calami*).  
 1847 *Streptelasma* Hall, legends Pl. 4, 12, 25.  
 1888 *Palaeocyathus* Foerste, p. 129.  
 1937 *Streptelasma* Cox, p. 2.

TYPE SPECIES (of *Streptelasma* by subsequent designation of Römer 1861, p. 19): *Streptelasma corniculum* Hall 1847, p. 69, Pl. 25, fig. 1, 'lower part of the rock' (Trenton Limestone), Trenton Falls, Middleville, Turin, Watertown 'and at numerous other localities', New York.

TYPE SPECIES (of *Palaeocyathus* by subsequent designation of Lang, Smith and Thomas 1940, p. 94): *Cyathophyllum australe* Foerste 1888, p. 128, Pl. 13, fig. 12-14, Silurian, Bowning Hill, N.S.W. This species has been redescribed by Hill (1940, p. 410, Pl. 12, fig. 18-23), who has chosen the specimen (British Museum (NH) R26519) figured in fig. 18, Pl. 12 of her work as lectotype, and may be either late Wenlockian or early Ludlovian.

REMARKS: Although the spelling *Streptoplasma* is repeated seven times in Hall (1847), it is clear from the etymological information given by him on page 17, that it is a *lapsus calami* for *Streptelasma*, which is so spelled in the plate legends.

The minimum stratigraphical range for *Streptelasma* is Trentonian to Wenlockian. Several corals have been described under this name from Lower and Middle Devonian beds in North America, Europe and Australia; however in no instance is the generic identification certain and some have already been removed to other genera.

*Streptelasma* (?) *vagans* sp. nov.

(Pl. 14, fig. 4, 6, 7; Fig. 1 a-c)

? 1939a Gen. et sp. indet., Hill, Pl. 15, fig. 12.

NAME DERIVATION: *L. vagans* = wandering.

MATERIAL: Holotype and paratypes 1, 2, UNE F8959-F8961 respectively, collected by the author from the Loyola Limestone (late Gedinnian or Siegenian) at Griffith's Quarry, about 10 kilometres SW. of Mansfield, Vict. These have provided 4 thin sections.

The specimen figured by Hill (1939) is a transverse section, catalogued UM TS623, and if conspecific, would be an exact topotype.

DIAGNOSIS: Ceratoid tetracoral approximately 20 mm in length and 11 mm in maximum diameter. Septal stereozone variable, up to 2.5 mm wide. Major septa approximately 20 in number, typically twisted at the axis forming a weak structure with the strongly inclined and axially elevated tabulae. Minor septa extremely short, or absent. Dissepiments lacking.

DESCRIPTION: Ceratoid tetracoral; before sectioning the incomplete holotype was approximately 12 mm long and 11 mm in greatest diameter; the paratypes were

just as fragmentary. The calice would be steep sided and there would probably be an axial boss.

A peripheral stereozone of dilated septal ends is variably developed. In the available material a maximum thickness of 2.5 mm is reached on what is believed to be the counter side of the holotype; elsewhere the thickness is as little as 0.5 mm. Septa are in two very unequal series. The major taper abruptly inside the stereozone and most are twisted and deflected from the axis; a few somewhat dilated axial lobes are present in the axial region. Minor septa are either confined to the peripheral stereozone, or only just project into the lumen. There are no dissepiments.

Tabulae are incomplete, gently convex and prominently elevated in the axial region. A few short flat tabellae may be present at the margin of the tabularium.

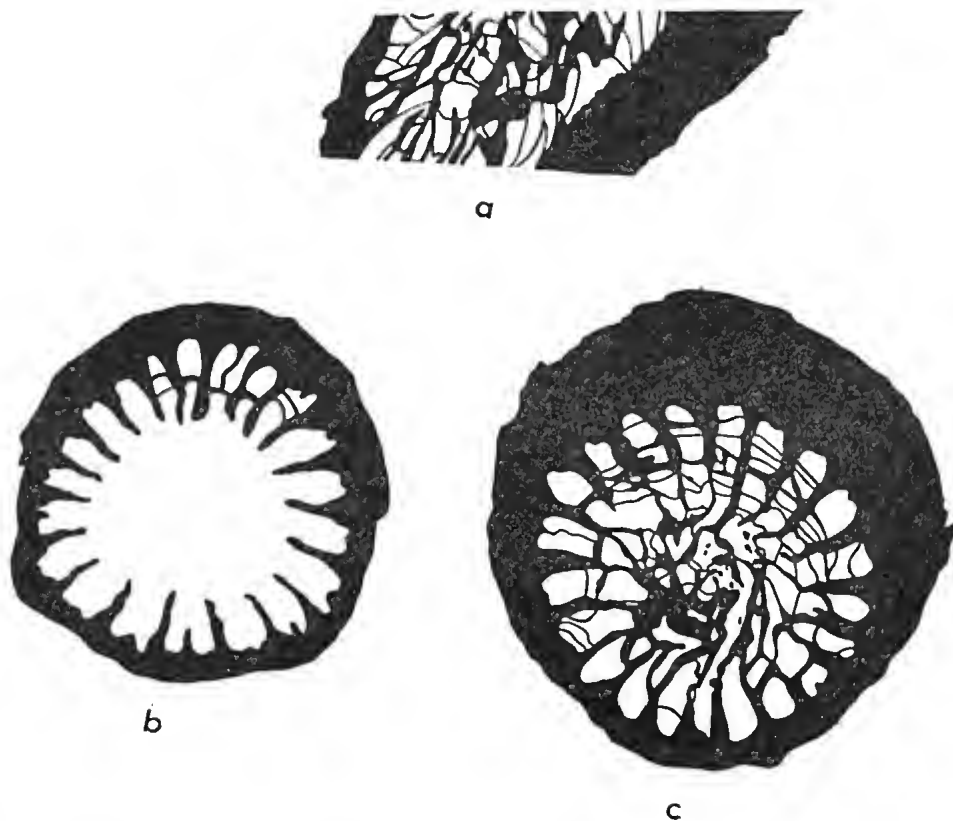


FIG. 1—*Streptelasma* (?) *vagans* sp. nov.,  $\times 5$ . (a) UNE F8959, holotype, longitudinal section; (b) UNE F8961, paratype, transverse section near base of calice; (c) UNE F8959, holotype, transverse section. Both from the Loyola Limestone near Mansfield, Vict.

REMARKS: The new species resembles *Streptelasma* more than most other Devonian species referred to the genus. However, the thickening of the peripheral stereozone on one side is an unusual feature, and is the reason for only doubtfully associating the species with it. Comparisons with other Lower Devonian species

are hampered in nearly every case by inadequacies in earlier descriptions. *S. cum-berlandicum* Swartz (1913, p. 199, Pl. 18, fig. 1, 2) from Maryland, *S. armoricum* Le Maître (1934, p. 146, 147, Pl. 5, fig. 1, 2) from France and *S. devonicum* Chernyshev (1885, p. 62, 63, Pl. 7, fig. 103) from the W slope of the Urals are all much larger with many more septa.

#### Family LINDSTROEMIIDAE Počta

1902 LINDSTRÖMIDAE Počta, p. 181, 182.

1925 LINDSTROEMIINAE Chapman, p. 105 (as subfamily of the Cyathaxoniidae).

1928 LACCOPHYLLIDAE Grabau, p. 82.

1928 LINDSTROEMIIDAE Počta, Grabau, p. 111 (justified emendation).

1939b SYRINGAXONIDAE Hill, p. 141, 142.

1939b METRIOPHYLLIDAE Hill, p. 143.

1953 STEREOCLASMATIDAE Fomichev, p. 96.

1965 DITOECHOLASMATIDAE Sutherland, p. 35, 36.

REMARKS: As will be evident from this synonymy, the present work is following Gliniski (1963) and Fedorowski (1965) in reviving the name Lindstroemiidae for a broad generic assemblage approximating to the combined Laccophyllidae, Metriophyllidae and Syringaxonidae of other current workers (Prantl 1938; Stumm 1949; Schouppé 1954; Hill in Moore 1956; Philip 1962; Flügel and Free 1962; Oliver 1964; Sutherland 1965). But this must be regarded as a provisional measure, for no doubt, natural, or purely utilitarian groupings will be recognized within such a broad family. At the moment two factors are obscuring the taxonomy and limits of these groupings. Firstly, the original, or lectotypic specimens of such vital genera as *Syringaxon*, *Lindstroemia* and *Ditoecholasma* have not been adequately described, and secondly, there is evidence, particularly from the present study, that some supposedly diagnostic features, such as metriophylloid carinae, must have evolved independently in different lineages.

*Lindstroemia* Nicholson and Thomson (1876, p. 150), is somewhat vaguely known and there has been confusion concerning the type species, which as Willoughby (1938) points out, is *L. columnaris*. Despite uncertainties surrounding the species, interior figures, justifying the Lindstroemiidae as a broad generic assemblage, have been provided by Nicholson and Etheridge (1878, Fig. 4b, 4b', p. 84) and are readily available in several subsequent works.

#### Genus *Haptophyllum* nov.

NAME DERIVATION: Gk, *απτο* = touch, and *φυλλον* = leaf.

TYPE SPECIES: *Metriophyllum erisma* Hill (*partim*). Holotype only, paratype = *Metriophyllum solidum* sp. nov., see below.

DIAGNOSIS: Small solitary tetracoral with broad lamellar epitheca. Septa predominantly paired, commonly contratingent and bearing metriophylloid carinae. Normal dissepiments absent, but inwardly inclined plates are developed within the septal pairs (position 1 of Sutherland 1965). Tabulae descend steeply from the axis and are confined to loculi exterior of the septal pairs (position II of Sutherland).

REMARKS: *Haptophyllum* is distinguished from *Metriophyllum* and *Metrioxaxon*, both discussed later in the paper, by possession of paired septa enclosing axially sloping plates. The late Ludlovian genus *Petraia* Münster (1839, p. 42) is a small coral with contratingent septa, but lacks carinae and typically also tabulae (Schindewolf 1931, p. 634). Compared with *Ditoecholasma* Simpson (1900, p. 200, 201, fig. 5, 6), another Ludlovian genus, *Haptophyllum* has carinae and lacks

an axial structure formed of lobed septal edges (Sutherland 1965, p. 36). *Saucrophyllum* Philip (1962, p. 172, 173, Pl. 22, fig. 1-8) from the early Ludlovian of Oklahoma and the late Silurian or early Devonian, or both, of Victoria, is another somewhat similar genus, but in it the septa are again smooth and are commonly united forming a tabulate aulos.

***Haptophyllum erisma* (Hill 1950)**

(Pl. 14, fig. 5; Pl. 15, fig. 3, 5; Pl. 16, fig. 1, 5, 7; Fig. 2a-d)

1950 *Metriophyllum erisma* Hill (*partim*), p. 142, Pl. 6, fig. 11 (*non* Pl. 6, fig. 12 = *Metriophyllum solidum*).

1964 *Metriophyllum erisma* Hill 1949 (*sic*), Holwill, p. 120.

**MATERIAL:** Holotype, GSV 48901 (longitudinal section), collected by Curt Teichert in the 'lower Murrindal beds', one-half mile N of Buchan R. Bridge (locality 167 of Teichert and Talent 1958), Vict. In current stratigraphical terms the type horizon falls in the Emsian Taravale Formation.

Topotypes, UNE F8962-F8965, collected by G. M. Philip and the writer. These have provided 13 thin sections.

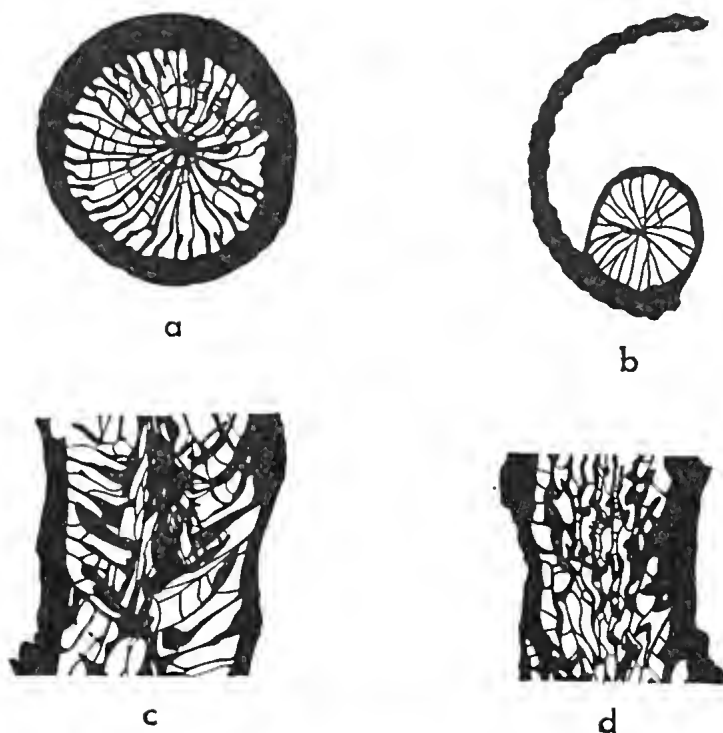


FIG. 2—*Haptophyllum erisma* (Hill) gen. nov.,  $\times 5$ . (a) UNE F8963, topotype, transverse section; (b) UNE F8964, topotype, transverse section of part of old calice and rejuvenated corallite; (c) UNE F8962, topotype, longitudinal section; (d) UNE F8962, topotype, tangential section. All from the Taravale Mudstone near Buchan, Vict.

**DIAGNOSIS:** Ceratoid to subcylindrical coral with maximum known diameter of 8.5 mm. Epitheca typically about 0.8 mm thick, maximum 1.3 mm. Septa mostly paired and commonly contratingent, varying in number from 33 to 43 in adult specimens. Carinae metriophylloid, inwardly descending, may mimic septa. Dissepiments absent, but axially inclined plates occur between the paired septa (position I). Tabulae confined to position II and exceptionally steeply inclined from the central region.

**DESCRIPTION:** Corallum solitary, ceratoid to subcylindrical; maximum observed length, which excludes both calice and proximal tip, 19.0 mm; maximum diameter 8.5 mm. Rejuvenescence of the type known in other lindstroemiids (Holwill 1964, Pl. 18, fig. 7; Fedorowski 1965, fig. 2f-h) is visible in UNE F8964.

Epitheca apparently lamellar, typically about 0.8 mm thick, locally increasing to 1.3 mm. Septa are normally paired and contratingent, the junction occurring at varying distances from the axis. Carinae are metriophylloid, inwardly sloping and may be sufficiently developed to mimic septa. In three topotypes septa are thin and several coalesce in the axial region, but in another (UNE F8965), they are thicker and form a rather dense axial structure. Septal counts with diameters given in mm are as follows:

Specimen	Status	Mean diameter	No. of Septa
UNE F8964	Topotype	2.9	25
UNE F8962	"	5.5	34
UNE F8963	"	6.3	36
UNE F8965	"	7.1	43
UNE F8963	"	8.2	34

There are no normal dissepiments, but plates occur between the septal pairs (position I); these tend to slope inwards, but on the whole are not as inclined as the carinae.

Tabulae are normally less than 1 mm apart and are so steeply inclined from the axial region that they may be almost vertical in places.

**REMARKS:** There is no close resemblance between *Haptophyllum erisma* and any other described species. Phylogenetically it may have been derived from a *Metriophyllum* such as *M. devexicarinatum*, described later in this paper, but sloping metriophylloid carinae are not necessarily the monopoly of one lineage, and the origin of *Haptophyllum* may equally well lie with a corals having smooth paired septa.

Browne (1959, p. 121) has reported 'an abundance of a small zaphrentid corals, *Metriophyllum* sp. (cf. *M. erisma* Hill . . .)' in the Waroo Limestone of the Taemas area, N.S.W. Specimens from this area and horizon have not been studied in connection with the present work and the reference has not been considered in the compilation of synonymies.

#### Genus *Taralasma* nov.

**NAME DERIVATION:** Tara Creek, near Buchan, Viet., and Gk., *πλασμα* = plate; unusually elided for the sake of euphony.

**TYPE SPECIES:** *Syringaxon radiatum* Hill 1950, redescribed below.

**DIAGNOSIS:** Small solitary tetraeorals. Septa smooth to weakly carinate, typically radially disposed and to some extent peripherally discontinuous; minor normally contratingent with the major. Imperfect aulos formed by dilation of the axial ends of

major septa. Dissepiments first appear in late neanic or early ephebic stages as plates between contratingent septa (position 1), but ultimately are well developed between all septa. Tabulae generally flat within the aulos and descending from it.

REMARKS: Hill originally assigned the type species to *Syringaxon* Lindström (1882, p. 20), and Philip (1962, p. 173) has suggested that it might be related to *Saucrophyllum*. Neither of these authors was fully aware of the extent and nature of the dissepimentarium, which together with the discontinuity of the septa in the more marginal region of the coral, distinguish it from species of either *Syringaxon* or *Saucrophyllum*. We are here, of course, following only the conventional concept of *Syringaxon* (Butler 1935; Prantl 1938; Smith 1945), for at present there is no adequate figure of the interior of the original specimen of *Cyathaxonia siluriensis* McCoy (1850, p. 281; Sedgwick and McCoy 1851, p. 36; 1855, Pl. 1C, fig. 11), the type species of *Syringaxon*.

Early stages of *Taralasma* resemble mature specimens of *Barrandeophyllum* Počta (1902, p. 190, 191, Pl. 108, fig. 4, 5, 7, 10, 13, 19) and perhaps also the poorly described *Retiophyllum* Počta (1902, p. 180, 181, Pl. 108, fig. 6), but again, the discontinuity of the septa near the periphery and the opulence of the adult dissepimentarium distinguish the new genus.

*Catactotoechus* Hill (1954, p. 9, 10, Pl. 2, fig. 30-33; Pl. 3, fig. 31-38) from the Famennian of W.A. possess sporadic dissepiments, but these apparently never constitute a well developed dissepimentarium and there are no minor septa in the genus.

Certain aspects of the morphology of *Taralasma radiatum* recall the Polish Middle Devonian species *Blothrophyllum skalense* Gürich (1896, p. 173-176, Pl. 4, fig. 1, 7, 8). Dembińska-Rózkowska (1949, p. 202, Fig. 11) and Fedorowski (1965, p. 346-348, Fig. 1E, Pl. 5, fig. 1-5) are in agreement with Gürich's generic assignment and Fedorowski goes further to recognize the *Blothrophyllinae* as a subfamily of the Lindstroemiidae. However, the similarity between *Blothrophyllum decorticum* Billings (1859, p. 130, Fig. 25), the Onondagan type species of the genus (Billings 1859, p. 129), and *B. skalense* is probably due to homeomorphy rather than phylogeny. In any case *Taralasma* is distinguished from either of these species by its contratingent septa and aulos.

### ***Taralasma radiatum* (Hill 1950)**

(Pl. 15, fig. 1, 2, 4, 6, 7; Fig. 3 a-c)

1950 *Syringaxon radiatum* Hill, p. 144, Pl. 6, fig. 14, 15.

MATERIAL: Holotype and paratype, GSV 48113 (transverse section) and GSV 48910 (longitudinal section) respectively; both collected by Curt Teichert in the 'Lower Murrindal beds', one-half mile N. of Buchan R. bridge (locality 167 of Teichert & Talent 1958), Vict. In current terms these originated in the Emsian Taravale Formation.

Topotypes, UNE F8966, F8967, collected by G. M. Philip and the writer; both have been cut to produce a total of 6 thin sections.

DIAGNOSIS: Corallum typically ceratoid with maximum observed length and width approximately 40 and 14 mm. Epitheca with variable lamellar reinforcement, locally up to 1.3 mm thick. Septa smooth to weakly carinate, radially disposed, minor contratingent with the major; both orders may be discontinuous across the dissepimentarium. Adult septal counts  $22 \times 2$  to  $24 \times 2$ . Imperfect aulos, with internal diameter 1.0 to 2.5 mm, formed of dilated septal ends. Dissepiments initially absent, first developed within septal pairs (position I), ultimately up to 5

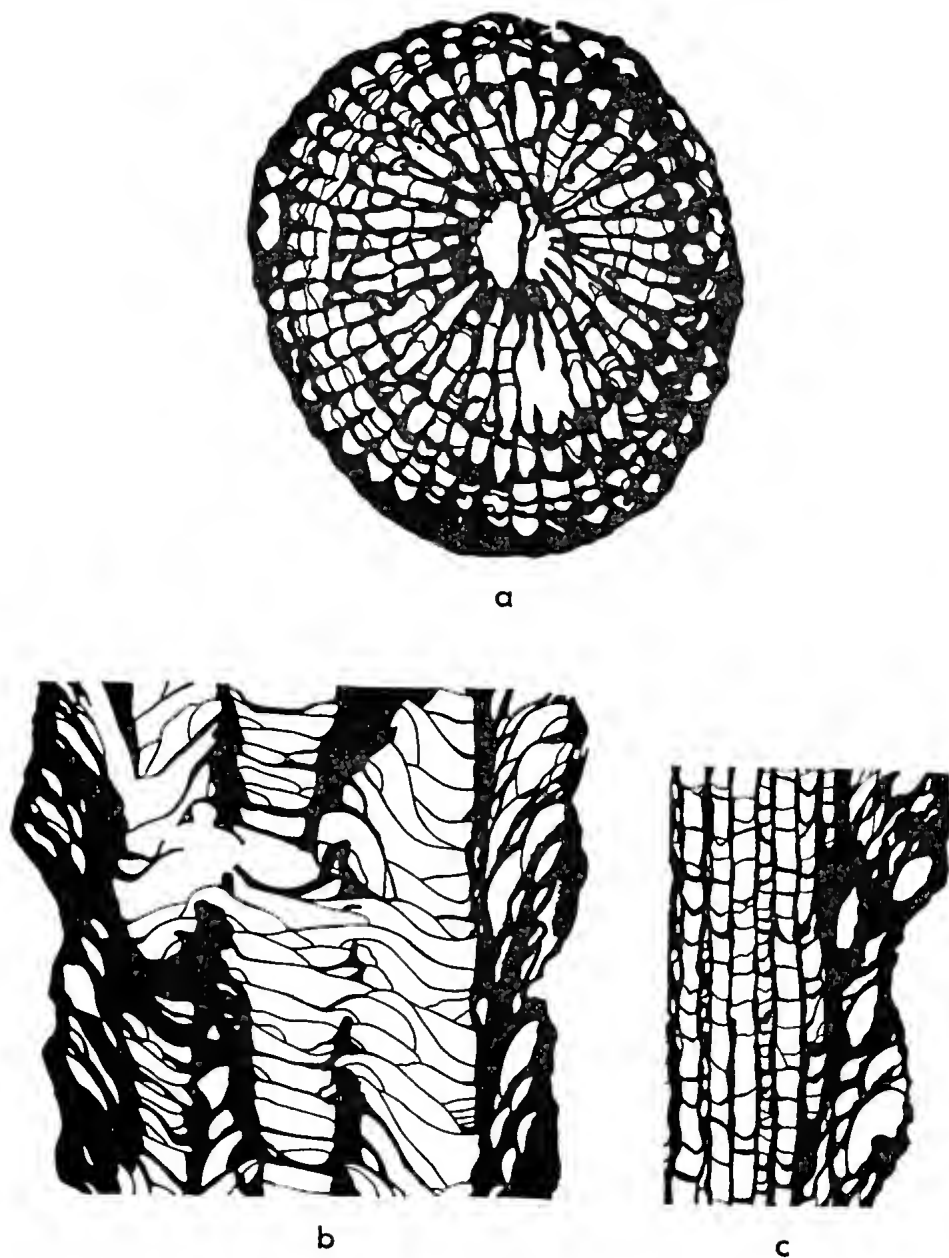


FIG. 3—*Taralasma radiatum* (Hill) gen. nov.,  $\times 5$ . (a) UNE F8966, topotype, transverse section; (b) UNE F8966, topotype, longitudinal section; (c) UNE F8966, topotype, part of a tangential section. Taravale Mudstone near Buchan, Vict.



deep between all septa. Aular tabulae generally flat; peripheral tabulae sigmoidal, outwardly inclined. Sclerenchyme commonly present on both dissepiments and tabulae.

**DESCRIPTION:** Corallum conical or ceratoid, less commonly subcylindrical, rejuvenated in some specimens. Large fragmentary specimens are 35 mm in length and 13 or 14 mm in diameter. Rugae and fine growth ridges mark the exterior, but the calice is unknown.

The epitheca may be thin, as in parts of UNE F8967, or as much as 1.3 mm in width, as in parts of UNE F8966, excess thickening being due to the presence of lamellar sclerenchyme at the periphery. Septa radially arranged, smooth to weakly carinate and differentiated into two orders; commonly they are discontinuous across the dissepimentarium and they may be slightly withdrawn from the periphery. Axial dilation of the major septa leads to the formation of an imperfect aulos, whose internal diameter varies between 1.0 and 2.5 mm. Minor septa are mostly contratingent with the major, the junction being situated in the outer part of the tabularium. Hill noted that in the paratype minor septa on either side of the counter septum are longer than others; this is also the case in UNE F8966, but not in other topotypes studied. Septal counts at diameters expressed in mm are as follows:

Specimen	Status	Mean diameter	No. of Septa
GSV 48113	Holotype	10.0	24 × 2
UNE F8966	Topotype	11.0	22 × 2
UNE F8966	"	12.6	22 × 2
UNE F8967	"	13.0	24 × 2

At first there are no dissepiments, but with the enlargement of the coral to a diameter of 7 mm or so, plates appear within the contratingent septa (position I). Higher these plates are replaced at the periphery by normal convex dissepiments, which are also introduced exterior of the septal pairs (position II), so that ultimately there is a continuous dissepimentarium. The dissepiments themselves are elongate, in a few cases lonsdaleoid, and most are invested with at least some sclerenchymc. In late stages, as seen for example in UNE F8966, the dissepimentarium may consist of as many as five rows of dissepiments and constitute one-third of the total radius of the coral.

The aular tabulae are typically complete and flat, and may be invested with sclerenchyme which merges with the wall of the aulos. Marginal tabulae are developed between different pairs of contratingent septa (position II) and descend towards the periphery in a graceful sigmoidal curve. A tangential section of UNE F8966 shows that plates in position I are more closely spaced than those in position II.

**REMARKS:** The presence of a well developed dissepimentarium with occasional lonsdaleoid dissepiments, in a second undoubted lindstroemiid, lends considerable support to the assignment of the next described species to the same family.

#### Genus *Tanjilasma* nov.

**NAME DERIVATION:** County of Tanjil, Viet., and Gk., *πλασμα* = plate; again unusually elided in the interests of euphony.

**TYPE SPECIES:** *Tabulophyllum* (?) *meridionale* Philip 1962, see below.

**DIAGNOSIS:** Small solitary tetracoral with relatively broad lamellar epitheca. Septa smooth, well differentiated into two orders, commonly peripherally discontinuous or withdrawn; major septa typically dilated axially, forming an imperfect aulos, and in places contratingent. Dissepiments steep, elongate, some lonsdaleoid. Tabularium prominently elevated in the region of the aulos.

**REMARKS:** The morphology and geological occurrence of the original specimen suggested that it might be either an early *Tabulophyllum* Fenton and Fenton (1924, p. 30, 31) or a late *Kiphophyllum* Wedekind (1927, p. 19, 20). However a newly acquired topotype has a better developed aulos and more numerous septa and dispels any doubts of the species' place among the Lindstroemiidae.

**REMARKS:** Several of the differences between *Tanjilasma meridionale* and *Taralasma radiatum* are in degree only. The important distinction between the species, and for that matter the genera, is that in *Taralasma* the horizontal or sub-horizontal elements in position I, differ from those in position II, whereas in *Tanjilasma* there is but one series of tabulae and dissepiments.

### ***Tanjilasma meridionale* (Philip 1962)**

(Pl. 14, fig. 8, 9; Fig. 4a, b)

1962 *Tabulophyllum* (?) *meridionale* Philip, p. 184, Fig. 6, Pl. 26, fig. 4, 5.

**MATERIAL:** Holotype, UM 3036, from which two thin sections have been prepared and registered UM TS1590, TS1591; collected by G. M. Philip in a limestone of the Coopers Creek Formation (late Gedinian or Siegenian) on Tyers R. (locality 15 of Philip 1962), Vict.

The specimen illustrated in this paper, UNE F8968, is an exact topotype and was collected by G. M. Philip and the writer; it is also now reduced to two thin sections.

**DIAGNOSIS:** Corallum ceratoid to subcylindrical, greatest known diameter 15 mm. Epitheca lamellar with maximum thickness 1.2 mm. Septa smooth, strongly differentiated, commonly peripherally discontinuous, or withdrawn, and approximately  $25 \times 2$  in number at maturity. Major septa dilated near the axis, locally contratingent forming an imperfect aulos. Minor septa rudimentary, mostly confined to the dissepimentarium. Dissepiments elongate, some lonsdaleoid, up to 6 deep. Tabulae incomplete, prominently elevated in the axial region.

**DESCRIPTION:** Corallum solitary, ceratoid to subcylindrical. The topotype, which was incomplete at both ends, was 18 mm long and 11.5 mm in mean diameter at the upper end; the holotype was a slightly larger specimen with a maximum diameter of 15 mm. The calice is unknown.

The epitheca appears to be essentially a lamellar stereozone and is confluent with sclerenchyme investing the bases of the septa and many of the dissepiments. It is 1.2 mm, or less, thick and bears prominent septal grooves and interseptal ridges; these have similar curvature, so that the exterior of the coral appears corrugated in transverse section. Septa are smooth and commonly withdrawn from the periphery, or discontinuous in the dissepimentarium. The major are dilated, and some are fused a short distance from the axis to form an irregular aulos. The minor are typically impersistent and confined to the dissepimentarium, a few join major septa just inside the margin of the tabularium, and in the topotype, those flanking the counter septum extend well into the tabularium. There are  $24 \times 2$  septa at 11.5 mm diameter in the topotype and  $25 \times 2$  at 14.00 mm in the holotype.

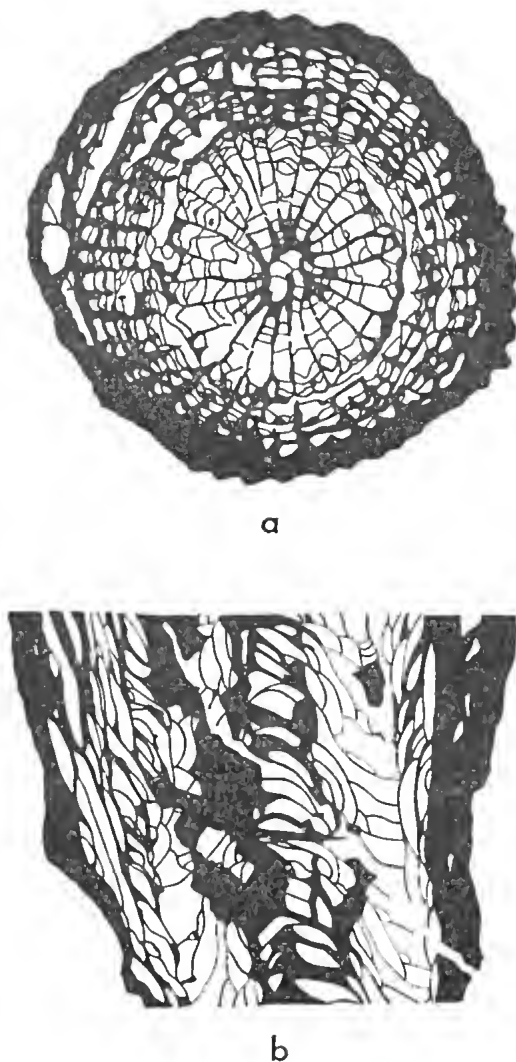


FIG. 4—*Tanjilasma meridionale* (Philip) gen. nov.,  $\times 5$ . (a) UNE F8968, topotype, transverse section; (b) UNE F8968, topotype, longitudinal section. Limestone in the Coopers Creek Formation, Tyers R., Vict.

Dissepiments are steeply inclined, elongate and in places lonsdaleoid; at the lower end of the topotype they are restricted to one or two rows, but higher in the corallite are 7 or 8 deep.

The tabulae are gently domed within the aulos, but immediately exterior of it are convex, steeply inclined, or even vertical, while towards the periphery they flatten considerably and may become concave.

Sclerenchyme commonly invests the axial terminations of the major septa as well as the aular tabulae.

Genus **Metriophyllum** Milne-Edwards and Haime

1850 *Metriophyllum* Milne-Edwards and Haime, p. lxi.

1851 *Metriophyllum*, Milne-Edwards and Haime, p. 317, 318.

1900 *Lopholasma* Simpson, p. 206, 207, Fig. 19, 20.

1940 *Lophelasma* Lang, Smith and Thomas, p. 80 (unjustified emendation).

1964 *Metriophyllum* Edwards and Haime 1850, Holwill (*partim?*) p. 109-111 (includes *Metrionaxon*).

TYPE SPECIES (of *Metriophyllum* by original designation): *M. bouchardi* Milne-Edwards and Haime 1850, p. lxi, *nomen nudum*, described 1851, p. 318, Pl. 7, fig. 1-2b, Ferques near Boulogne, France. Lang Smith and Thomas 1940, p. 84 have designated the coral figured in Pl. 7, fig. 1, 1a as lectotype. Rigaux (1892, p. 18) and other subsequent workers list this coral only from the Frasnian Beaulieu Shale and Ferques Limestone, but Holwill (1964, legends Pl. 16, 17) figures specimens stated to be from the Middle Devonian.

TYPE SPECIES (of *Lopholasma* and *Lophelasma* by original designation): *Streptelasma rectum* Hall (*partim*) 1876, Pl. 19 (*non Strombodes* (?) *rectus* Hall 1843, p. 210, Fig. 87.5 = *Stereolasma rectum*, see Stumm and Watkins 1961, p. 445, 446, Pl. 58, fig. 1-16), Hamilton Group (Givetian) at several localities in New York. This species was named *L. carinatum* by Simpson 1900, p. 206 and syntypes were later figured by Holwill 1964, Pl. 16, fig. 1-3.

REMARKS: The limits imposed on the genus in Holwill's (1964) useful review, would seem to be too broad in the light of Glinski's (1963) work. These authors have independently studied the primary material of *Metriophyllum laeve*, a species tentatively erected by Schlüter (1889, p. 20), and apparently unknowingly have arrived at very different conclusions, for whereas Glinski recognizes both *Syringaxon* and a new genus, *Metrionaxon*, in the material, Holwill believes that it includes merely the gerontic forms of *Metriophyllum gracile* Schlüter (1884, p. 82, 83; 1889, p. 18-20, Pl. 2, fig. 5-8). Evaluation of such contrasting opinions is not possible at this distance, but as *Metrionaxon*, which is characterized by having metriophylloid carinae together with a tabulate aulos, has been found to be a usable genus in Poland (Federowski 1965, p. 340-342), it seems reasonable to continue its recognition, especially in view of the abundance of the Polish material.

Some Victorian specimens of *Metriophyllum*, particularly those of *M. solidum murrindalense*, are sufficiently similar to *Duncanella pontotocensis* Sutherland, (1965, p. 41, 42, Pl. 33, fig. 1-5; Pl. 34, fig. 8) from the Ludlovian of Oklahoma, to cast doubt on the validity of *Duncanella* Nicholson (1874, p. 333) as a distinct genus. The species referred to *Duncanella* in early literature (Nicholson 1874, p. 334, 335, Fig. a-e on p. 334; Schlüter 1885, p. 6; 1889, p. 16-18, Pl. 2, fig. 9-15 and Girty 1895, p. 299, Pl. 2, fig. 7, 8) lack epithecal cover on the apex. In *D. pontotocensis* this is a variable feature, and on the basis of the tangential figure (Sutherland 1965, Pl. 33, fig. 4b), the subhorizontal elements visible in longitudinal sections are metriophylloid carinae rather than tabulae. Such carinae were not described by Nicholson in *D. borealis*, the type species from the Waldron Formation (Ludlovian?) of Indiana, and Hill's (in Moore 1956, p. 257) diagnosis of the genus specifically notes that the septa are unflanged. Although *D. borealis* is yet another species in need of further study (Sutherland 1965, p. 41), at the moment there is insufficient evidence for regarding it as a synonym of *Metriophyllum*, which in any case would stand as the senior name.

***Metriophyllum devexicarinatum* sp. nov.**

(Pl. 16, fig. 10, 11, 14, 16; Fig. 5a-c)

1962 *Syringaxon* (*Barrandeophyllum*) sp., Philip (*partim*), p. 172 (one or two unfigured specimens only).

NAME DERIVATION: *L. devexus* = inclined, and *carinatus* = carinate.

MATERIAL: Holotype, UNE F8969, collected by G. M. Philip and the writer from a limestone in the Coopers Creek Formation (late Gcdinnian or Siegenian) on Tyers R. (locality 15 of Philip 1962), Vict. Paratype, UM TS1186, TS1187 (same specimen), collected by G. M. Philip in the same limestone at his locality 20.

UM TS1188, also collected by G. M. Philip from the same limestone (his locality 28), is probably another example of the species, but is not to be regarded as a paratype.

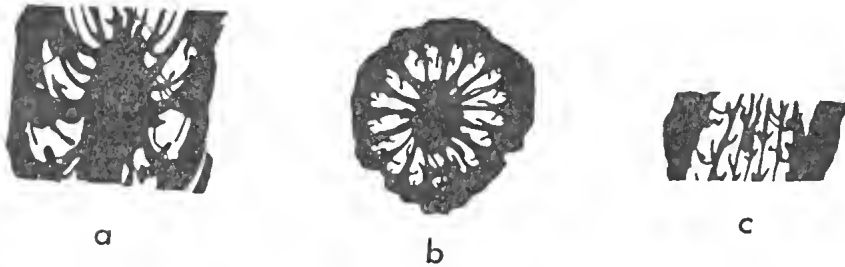


FIG. 5—*Metriophyllum devexicarinatum* sp. nov.,  $\times 5$ . (a) UNE F8969, holotype, longitudinal section; (b) UNE F8969, holotype, transverse section; (c) UNE F8969, holotype, tangential section. Limestone in the Coopers Creek Formation, Tyers R., Vict.

DIAGNOSIS: Small ceratoid coral with an approximate diameter of 5 mm. Epitheca relatively thick. Septa of one order only, axially fused, 18 in number in the holotype, and bearing inwardly sloping flange carinae. Dissepiments absent. Tabulae few and outwardly sloping.

DESCRIPTION: The holotype is an erect ceratoid coral approximately 5 mm in greatest diameter, and although lacking a proximal tip, was 14 mm in length before sectioning. Two transverse sections and one other, which due to movement along a stylolite, is partly longitudinal and partly tangential, have been prepared from it.

In transverse section the epitheca is corrugated and varies in thickness from about 0.5 to 1.0 mm; it is mainly constituted of lamellar sclerenchyme which not only embeds the septa, but also extends for some distance along their sides.

There is no indication of minor septa in either the lumen, or the fine structure of the epitheca. The major septa number 18 in both available sections and are dilated and fused at the axis forming a relatively stout pseudocolumella; flange carinae are well developed and are unusual in that they slope from the epitheca at about  $45^\circ$ . There are no dissepiments. Tabulae are few and are inclined steeply in the direction opposite to the carinae.

REMARKS: Several Devonian species referred to *Metriophyllum*, for example *M. elsii* Whidborne 1901, p. 538; *M. (?) irregulare* Paeckelmann 1921, p. 143-145, Pl. 3, fig. 15; *M. volki* Weissmerl 1939, p. 361, 362, Pl. 14, fig. 8-10; *M. cruciferum* Weissmerl 1941, p. 170, 171, Pl. 5, fig. 3, are too poorly known to allow comparisons. As far as the adequately described species are concerned, *M. devexi-*

*carinatum* is rendered almost unique by the inclination of the carinae; only *Duncanella* (?) *pontotocensis* Sutherland has similarly inclined carinae, but in that species they are much less prominent.

Six thin sections, from five specimens of the coral identified by Philip as *Syringaxon* (*Barrandeophyllum*) sp., have been studied in Melbourne. Three of these (UM TS1184, TS1185, TS1189) are probably conspecific, but in the absence of longitudinal sections, their generic identity remains conjectural. Another specimen (UM TS1188) bears carinae and further resembles the holotype of *M. devexicarinatum* in having 18 septa at 5 mm diameter, but as a transverse section only is available, firm identification is not possible. The fifth specimen has been cut to produce both transverse and longitudinal sections (UM TS1186, TS1187) and is beyond doubt a specimen of *M. devexicarinatum*; it is, in fact, designated a paratype.

***Metriophyllum solidum* sp. nov.**

It is not clear at the moment whether differences between specimens from the Murrindal and Taravale Formations are due entirely to environmental factors, or whether they also reflect some temporal discrepancy. In any event two distinct communities appear to be represented, and it is proposed to erect two subspecies for them.

***Metriophyllum solidum solidum* sp. et subsp. nov.**

(Pl. 16, fig. 2, 3, 8, 9, 12, 13, 17; Fig. 6a, b, d-f)

1950 *Metriophyllum erisma* Hill (partim), p. 142, Pl. 6, fig. 12 only (non Pl. 6, fig. 11 = holotype of *Haptophyllum erisma*).

NAME DERIVATION: *L. solidus* = solid.

MATERIAL: Holotype and paratypes 1-8, UNE F8970-F8978 respectively, collected by G. M. Philip and the author from the Taravale Mudstone (Emsian) at the entrance to Buchan Caves Reserve, Viet. Paratypes 9, 10, UNE F8979, F8980, collectors as above, Taravale Mudstone, 800 metres N. of Buchan River Bridge, Viet. (locality 167 of Teichert and Talent 1958).

The entire type series has been sectioned and now consists of 21 thin sections.

The specimens figured by Hill are mounted on a single slide, registered GSV 47904, and were collected by Curt Teichert from 'Lower Murrindal beds' in a cutting on the old road to S. Buchan, one-quarter mile S of Buchan (locality 3 of Teichert and Talent 1958); these beds now constitute part of the Taravale Mudstone and are also believed to be Emsian.

DIAGNOSIS: Ceratoid tetracoral, approximately 25 mm along the convex side and 4 to 5 mm in diameter. Epitheca lamellar. Septa of one order only, numbering 16 to 18 at maturity, initially dilated displacing the entire lumen and somewhat pinnate in arrangement, subsequently less dilated, except axially where dilation produces a prominent pseudocolumella. Flange carinae present. Dissepiments and tabulae absent.

DESCRIPTION: Corallum ceratoid, small; the holotype, which is the largest specimen yet seen, measured about 27 mm along the convex side and 5.2 mm in greatest diameter.

The fine skeletal structure of the epitheca is the same as that figured in the type species by Wang (1950, Pl. 4, fig. 5) and Holwill (1964, Pl. 16, fig. 6) and consists of lamellar tissue, which not only embeds the slender septal ends, but also extends for a short distance along the sides of the septa. The apex is missing from all the available specimens. In the earliest stages preserved, septa are greatly dilated, typically displacing the entire lumen, the cardinal septum is prominent and extends

beyond the axis while the adjacent septa are much shorter and either abut it, or are weakly pinnate about it. In later stages interseptal loculi appear and the symmetry of the septa becomes more or less radial, even though the cardinal septum may remain larger than others. Axial dilation produces a prominent pseudocolumella. There is no trace of septa in the most distal part of the calice. Well developed flange carinae occur in all specimens and slope towards the axis; in the only tangential section available (UNE F8972) they are developed on alternate surfaces of the septum. Septa are of one order, and number, at given diameters in mm, as follows:

Specimen	Status	Mean diameter	No. of septa
UNE F8974	Paratype 4	2.7	16
UNE F8977	" 7	3.0	14
UNE F8973	" 3	3.5	15
UNE F8979	" 9	4.0	16
UNE F8973	" 3	4.1	16
UNE F8977	" 7	4.1	17
UNE F8974	" 4	4.2	18
UNE F8979	" 9	4.3	16
UNE F8976	" 5	4.5	18
UNE F8971	" 1	5.0	18

There are no dissepiments, and tabulae, if present at all, are extremely rare.

REMARKS: *Metriophyllum gracile* Schlüter, from the German Eifelian, is comparable in size (provided *M. laeve* is not admitted into synonymy—see under *Metrionaxon*), but has finer septa and tabulae. Attachment grooves, which occur on as many as two-thirds of the specimens of *M. gracile* at one locality (Holwill 1963), have not been observed on *M. solidum*.

*M. deminutivum* Easton (1944, p. 31, 32, Pl. 3, fig. 1-3) from the Chouteau Limestone of Missouri is also of similar size; however in that species the septa are unusually grouped, as well as being less dilated in early stages.

The pronounced pseudocolumella and virtual absence of tabulae in *M. solidum* recall *M. tullium* (Williams), from the late Givetian or early Frasnian Tully Formation of New York (Cooper and Williams 1935, p. 837, 838, Pl. 58, fig. 1, 2, 5, 9) and Pennsylvania (Willard 1937, p. 1249, Pl. 2, fig. 16, 28). But the Tully species is larger, and is provided with about 20 slender septa.

***Metriophyllum solidum murrindalense* sp. et subsp. nov.**

(Pl. 16; fig. 4, 6; Fig. 6c)

? 1958 single corals, Teichert and Talent (*partim*), stratigraphical column in Pl. 1, fig. 4.

NAME DERIVATION: Murrindal R., near Buchan, Vict.

MATERIAL: Holotype and paratypes 1-3, UNE F8981-F8984 respectively, collected by the writer approximately 175 ft below the top of the Murrindal Limestone (Emsian) on McLarty's Ridge section, Viet. Teichert and Talent (1958, Pl. 1, fig. 4) reported 'single corals' from this horizon.

These specimens are now reduced to 8 thin sections.

DIAGNOSIS: Subspecies distinguished from the nominate subspecies in details of size, septa, carinae and tabulae, the greatest known diameter being 7.5 mm and the maximum number of major septa 19 (5.2 and 18, respectively, in *M. solidum solidum*). Minor septa are well developed in late stages and the carinae typically

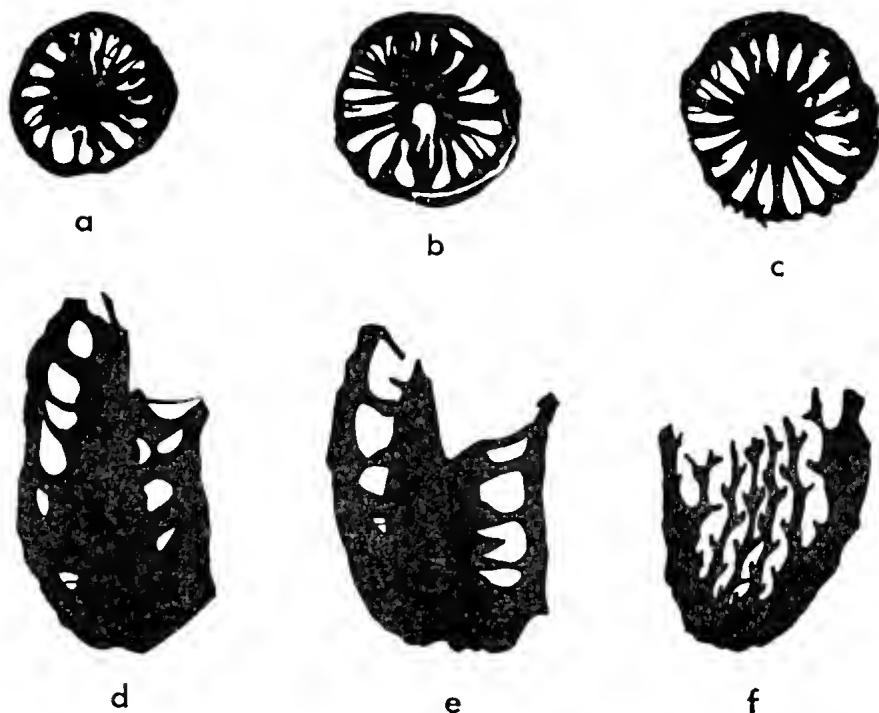


FIG. 6—(a, b, d-f) *Metriophyllum solidum solidum* sp. et subsp. nov.,  $\times 5$ . (a, b) UNE F8979, paratype, transverse sections; (d) UNE F8975, paratype, longitudinal section; (e) UNE F8972, paratype, longitudinal section; (f) UNE F8972 paratype, tangential section. All from the Taravale Mudstone, near Buchan, Vict. (c) *Metriophyllum solidum murrindalense* sp. et subsp. nov.,  $\times 5$ . UNE F8982, paratype, transverse section. About 175 feet below the top of the Murrindal Limestone, near Buchan, Vict.

bridge the loculi between them and the major septa. The carinae thus simulate tabulae, which may also be present, but are distinguished by their free inner margin and much greater thickness.

REMARKS: As intimated in the discussion of the genus, there is an unmistakable similarity between this subspecies and *Duncanella* (?) *pontotocensis* Sutherland. However the new subspecies is larger and has more numerous and more dilated major septa as well as longer minor septa.

*M. delawareense* Baker (1945, p. 141, Pl. 3, fig. 9-11) from the Frasnian of Ohio, is similar in size, but in it, the septa are only 12 in number at 7 mm diameter, are undilated, and produce an inconspicuous columella.

#### Genus *Boolelasma* nov.

NAME DERIVATION: Parish of Boola Boola, Vict. and Gk, *πλασμα* = plate.

TYPE SPECIES: *Boolelasma pycnotheca* gen. et sp. nov., described below.

DIAGNOSIS: Small solitary tetracoral with relatively broad lamellar epitheca. Septa contratingent, united axially forming a regular narrow aulos, which may



become breached in latest stages. Metriophylloid carinae sporadically developed. Tabulae flat in aulos, inwardly sloping between them (position II).

REMARKS: The narrow aulos is identical with that found in the Middle Devonian genus *Metrionaxon* (Gülich 1896, Pl. 4, fig. 3; Sobolev 1904, Pl. 5, fig. 5; Pl. 7, fig. 2, 3; Glinski 1963, Fig. 1-3, Pl. 45, fig. 1, 2; Fedorowski 1965, Fig. 1B, Pl. 1, fig. 5-8; Pl. 3, fig. 1, 2; Pl. 4, fig. 1). In other respects resemblance between the genera is rather superficial, since in *Boolelasma* the septa are consistently contra-tingent and the peripheral tabulae fall into two series of opposite inclination.

*Haptophyllum*, described earlier in this work, is distinguished mainly by the absence of an aulos, but also by more abundant carinae.

*Barrandeophyllum* Počta (1902, p. 190, 191, Pl. 108, fig. 4, 5, 7, 13, 19) and the similar, if not synonymous, genus *Saucrophyllum* Philip (1962, p. 172, 173, Pl. 22, fig. 1-8) are differentiated by the complete absence of carinae.

Transverse sections of *Schindewolfia*, proposed by Weissmermel (1943, p. 24-26, Pl. 3, fig. 3-6) as a subgenus of *Lindstroemia*, suggest a similarity between it and the new genus. However there are no carinae in *Schindewolfia*, and if Weissmermel's interpretation of the type species is correct, connections visible between the septa are threads rather than dissepiments or tabulae.

***Boolelasma pycnotheca* sp. nov.**

(Pl. 16, fig. 15, 18-21; Fig. 7a-c)

NAME DERIVATION: Gk., *πυκνός* = thick, and *θήκη* = sheath.

MATERIAL: Holotype and paratypes 1-3, UNE F8985-F8988 respectively, collected by G. M. Philip and the author from a limestone in the Coopers Creek Formation (late Gedinian or Siegenian) at Philip's (1962, p. 125) locality 15 on Tyers R., Vict. The entire type series has been sectioned and now consists of 7 thin sections.

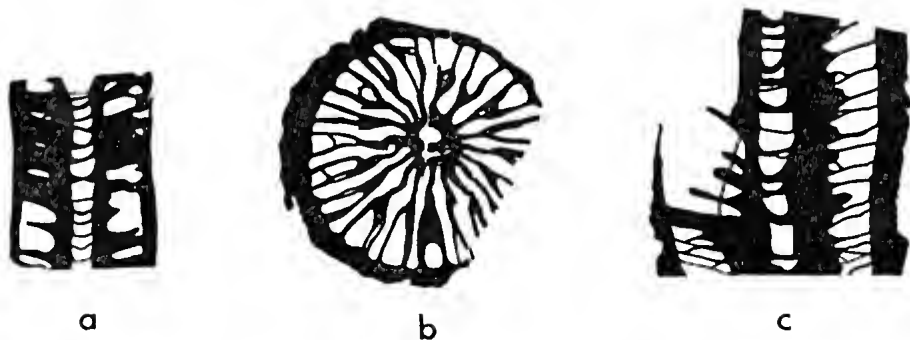


FIG. 7—*Boolelasma pycnotheca* gen. et sp. nov.,  $\times 5$ . (a) F8986, paratype, longitudinal section; (b) UNE F8985, holotype, transverse section; (c) UNE F8985, holotype, longitudinal section. Both from a limestone in the Coopers Creek Formation, Tyers R., Vict.

DIAGNOSIS: Ceratoid to subcylindrical tetracoral with adult diameter of about 5 to 7 mm. Epitheca lamellar, not known to exceed 1.2 mm in thickness. Septa normally contra-tingent, axially united to form a regular aulos, 18 or 19 in number at maturity. Metriophylloid carinae sparsely developed. Aular tabulae flat and

commonly invested by sclerenchyme. Peripheral tabulae abundant and predominantly gently inclined towards the axis within pairs of contratingent septa (position I), and much less abundant and steeply inclined from the axis between them (position II).

**DESCRIPTION:** Corallum small, ceratoid to sub-cylindrical with a deep parallel sided calice. The largest of the four available specimens (the holotype) although incomplete at both ends, was 19 mm in length and 7 mm in diameter before sectioning. No details of the exterior were exposed, but undulations in the wall, seen in transverse section, indicate the presence of longitudinal ridges.

The entirely lamellar wall is between 0.8 and 1.2 mm thick and appears to merely touch, rather than embed the septa. Throughout most of the coral's development the septa are contratingent, undifferentiated and are united towards the axis forming a regular aulos of 0.6 to 0.8 mm internal diameter. In latest stages, as in UNE F8988, the aulos may open, and it may be possible to distinguish major and minor septa. Metriophylloid carinae are developed sporadically and typically just slope towards the axis. Septal counts at given diameters expressed in mm are as follows:

Specimen	Status	Mean diameter	No. of septa
UNE F8986	Paratype 1	3.5	16
UNE F8985	Holotype	5.3	18
UNE F8988	Paratype 3	6.5	19
UNE F8885	Holotype	7.0	19

Flat tabulae, averaging about 2 per mm are present in the aulos and are commonly invested with sclerenchyme which merges into the aular wall. Tabulae inside the paired contratingent septa (position I) are as abundant as those in the aulos, and for the most part approximate in inclination to the carinae, although outwardly sloping plates may be present along the inner side of the intersseptal loculi. Exterior of the septal pairs (position II) tabulae are very much less abundant and where present slope steeply towards the periphery. Normal dissepiments are unknown in the species.

**REMARKS:** The possibility of confusing *Boolelasma pycnotheca* with other described species is remote, for as noted in the discussion of the genus, similarity with other lindstroemiids, such as the two described species of *Metriaxon*, is superficial.

#### Family AMPLEXOCARINIIDAE Soshkina

1941 AMPLEXOCARININAE Soshkina in Soshkina, Dobrolyubova and Porfirev, p. 92 (as sub-family of the Polyoelidae).

1965 AMPLEXOCARINIIDAE Rózkowska (in MS) Fedorowski, p. 350.

#### Genus *Amplexocarinia* Soshkina

1922 *Depasophyllum* Grabau, p. 21, 22 (*nomen nudum*).

1928 *Amplexocarinia* Soshkina, p. 379.

1936 *Depasophyllum* Grabau, p. 43, 44.

1940 *Amplexicarinia* Lang, Smith and Thomas, p. 16 (unjustified emendation).

1949 *Depasophyllum* Grabau, Stumm, p. 30.

1963 *Amplexocarinia* Soshkina, Smith and Thomas, p. 161, 162.

non 1934 *Depasophyllum* Yü, p. 19, 23, 24, 85, 86 (type species not fixed).

**TYPE SPECIES** (of *Amplexocarinia* and *Amplexicarinia* by original designation): *Amplexus* (*Amplexocarinia*) *muralis* Soshkina 1928, p. 379, 380, Fig. 19a-f. Lower Permian (Artinskian), Shehughor R., N. Urals.

**TYPE SPECIES** (of *Depasophyllum* by original designation): *D. adnetum* Grabau 1936, p. 44. Traverse Group (Givetian) of Michigan, and Onondaga Limestone (Eifelian) of New York. Figures and descriptions of syntypes and hypotypes from the Four Mile Dam Formation are given by Ehlers and Stumm 1949, p. 30, 31, Pl. 2, fig. 4-9; Pl. 8, fig. 11-15. The reported Onondagan occurrence remains unsubstantiated.

**REMARKS:** As far as the present record is concerned, the genus first appears in Victoria in beds of probable Siegenian age. It then reappears in the Eifelian and Givetian, including the Tully Limestone of possible early Frasnian age, in North America and Europe (Grabau 1936; Stumm 1960; Smith and Thomas 1963), and again in the late Tournaisian of England (Smith 1955) and Montana (Sando 1960) and the late Viséan of Queensland (Hill 1934, Pl. 11, fig. 12-29). In its final appearances during the Pennsylvanian and Permian *Amplexocarinia* achieved an almost cosmopolitan distribution (Soshkina 1928, 1932; Heritsch 1936, 1937, 1939, 1941; Felser 1937; Moore and Jeffords 1945; Schouppé and Stacul 1959; Fontaine 1961; De Groot 1963).

In view of the breaks in this record, a polyphyletic origin for the species presently referred to *Amplexocarinia* seems highly probable. Accordingly, the brief synonymy given above should be regarded as provisional.

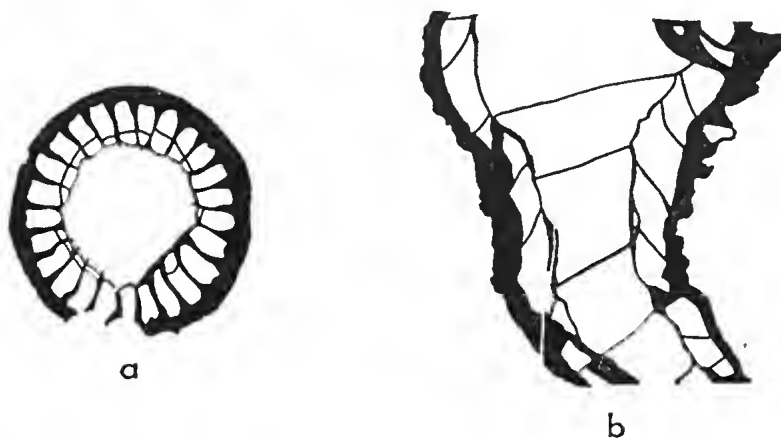


FIG. 8—*Amplexocarinia* (?) *fistella* sp. nov.,  $\times 5$ . (a) UNE F8989, holotype, transverse section; (b) UNE F8990, paratype, longitudinal section. Both from the Loyola Limestone near Mansfield, Vict.

***Amplexocarinia* (?) *fistella* sp. nov.**

(Pl. 14, fig. 1-3; Fig. 8a, b.)

**NAME DERIVATION:** L., *fistella* = small tube.

**MATERIAL:** Holotype and paratype, UNE F8989, F8990 respectively, collected by the writer from the Loyola Limestone (late Gedinnian or Siegenian) at Griffith's Quarry, about 10 kilometres SW. of Mansfield, Vict. These are now represented by 4 thin sections.

**DIAGNOSIS:** Small ceratoid to scolecoïd coral with maximum diameter approaching 8.5 mm. Epitheca 0.2 to 0.5 mm in width between septal bases. Septa 1.0 to

1.5 mm long, 23 to 24 in number. Aulos partly a cyathotheca, approximately 3 mm in diameter. Tabulae 1.0 to 2.5 mm apart, horizontal and complete in the aulos, but more abundant and outwardly inclined outside it.

DESCRIPTION: Both types were fragmentary and of the order of 15 mm in length when collected. Evidently there is variation in the growth for while the holotype is scolecoïd and approximately 7.0 mm in diameter, the paratype is ceratoid and 8.3 mm in diameter at the greater end.

Various irregularities characterize the outer wall, which is typically 0.2 to 0.5 mm wide between the septal bases, and a prominent attachment process is present in the transverse section of the paratype. Although not well preserved in fine detail, the outer wall appears to be partly lamellar and partly due to expanded terminations of the septa. Septa are 1.0 to 1.5 mm in length and 23 or 24 in number, and unless occasional protruberances between them represent minor septa, are of one order only.

An aulos, approximating to 3 mm in diameter is present; generally it is of the type known as a cyathotheca (Grabau 1922, p. 21) and is formed of the descending parts of superposed pill-box tabulae, but locally, deflected septal ends are incorporated into its structure. The pill-box tabulae are essentially horizontal and in the axial region are from 1.0 to 2.5 mm apart. The outer tabulae are slightly more numerous and are inclined towards the periphery. There are no dissepiments.

REMARKS: *A. (?) tortuosa* (Philips 1841, p. 8, Pl. 3, fig. 8), from the Givetian of western and central Europe, generally possesses a narrower epitheca, shorter septa, and an aulos of relatively greater diameter. But as some specimens from Poland (Fedorowski 1965, Pl. 4, fig. 2, 4-6) approach, if not equal the new species in these respects, it is probably more reliably distinguished by a scolecoïd, rather than ceratoid to subcylindrical growth form and by the exceptional irregularities in its epitheca.

Other Givetian species are less likely to be confused. The American *A. (?) adnetum* and *A. (?) tabulatum* (Stumm 1960, p. 162, Pl. 30, fig. 11-13), which is possibly early Frasnian, have uniformly shorter septa, besides the more regular form of their corallites. *A. (?) immissa* (Maurer 1885, p. 87-89, Pl. 1, fig. 19-20) from Germany, is a smaller species with only 18 septa.

*A. corrugata* (Mather 1915, p. 90, 91, Pl. 1, fig. 7-10; Cronies 1930, p. 84, Pl. 21, fig. 4, 5; Moore and Jeffords 1945, p. 142, Fig. 126-140), from the Lower Pennsylvanian of Oklahoma, Arkansas and Texas, is similar to *A. (?) fistella* in size and septal count, but the aulos is a true cyathotheca and no peripheral tabulae have been observed in the species.

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## Explanation of Plates

L.S. and T.S. are abbreviations used throughout for longitudinal and transverse sections respectively.

## PLATE 14

All figures  $\times 5$

- FIG. 1-3—*Amplexocarinia* (?) *fistella* sp. nov. (1) UNE F8989, holotype, L.S.; (2) UNE F8990, paratype, T.S.; (3) UNE F8989, holotype, T.S. Both from the Loyola Limestone, near Mansfield, Vict.
- FIG. 4, 6, 7—*Streptelasma* (?) *vagans* sp. nov. (4) UNE F8959, holotype, T.S.; (6) UNE F8960, paratype, T.S.; (7) UNE F8959, holotype, L.S. Both from the Loyola Limestone, near Mansfield, Vict.
- FIG. 5—*Haptophyllum erisma* (Hill) gen. nov., UNE F8964, topotype, T.S. From the Taravale Mudstone, near Buchan, Vict.
- FIG. 8, 9—*Tanjilasma meridionale* (Philip) gen. nov. (8) UNE F8968, topotype, T.S.; (9) UNE F8968, topotype, L.S. Limestone in the Coopers Creek Formation, Tyers R., Vict.

## PLATE 15

All figures  $\times 5$

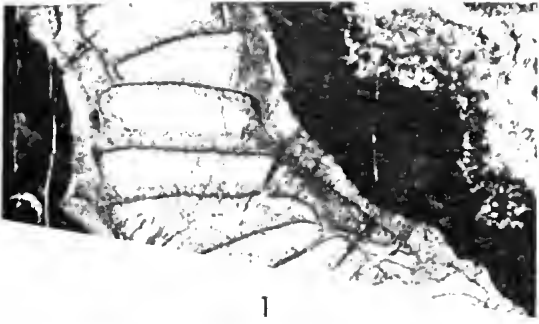
- FIG. 1, 2, 4, 6, 7—*Taralasma radiatum* (Hill) gen. nov. (1) UNE F8966, topotype, tangential section; (2) UNE F8967, topotype, L.S.; (4) UNE F8966, topotype, T.S.; (6) UNE F8966, topotype, L.S.; (7) UNE F8967, topotype, T.S. Both from the Taravale Mudstone, near Buchan, Vict.
- FIG. 3, 5—*Haptophyllum erisma* (Hill) gen. nov. (3) UNE F8962, topotype, tangential section; (5) UNE F8962, topotype, L.S. From the Taravale Mudstone near Buchan, Vict.

## PLATE 16

All figures  $\times 5$

- FIG. 1, 5, 7—*Haptophyllum erisma* (Hill) gen. nov. (1, 7) UNE F8963, topotype, T.S.; (5) UNE F8962, topotype, T.S. Both from the Taravale Mudstone near Buchan, Vict.
- FIG. 2, 3, 8, 9, 12, 13, 17—*Metriophyllum solidum solidum* sp. et subsp. nov. (2, 3) UNE F8974, paratype, T.S.; (8) UNE F8972, paratype, tangential section; (9) UNE F8973, paratype, T.S.; (12) UNE F8970, holotype, L.S.; (13) UNE F8975, paratype, L.S.; (17) UNE F8971, paratype, L.S. All from the Taravale Mudstone near Buchan, Vict.
- FIG. 4, 6—*Metriophyllum solidum murrindalense* sp. et subsp. nov. (4) UNE F8981, holotype, T.S.; (6) UNE F8982, paratype, T.S. From 175 feet below the top of the Murrindal Limestone, near Buchan, Vict.
- FIG. 10, 11, 14, 16—*Metriophyllum devexicarinatum* sp. nov. (10) UNE F8969, holotype, T.S.; (11) UM TS1187, paratype, near L.S.; (14) UNE F8969, holotype, L.S. above, and tangential section below stylolite; (16) UM TS1186, paratype, near T.S. Both from a limestone in the Coopers Creek Formation, Tyers R., Vict.
- FIG. 15, 18-21—*Boolelasma pycnotheca* gen. et sp. nov. (15) UNE F8985, holotype, near T.S.; (18) UNE F8985, holotype, T.S.; (19) UNE F8986, paratype, L.S.; (20) UNE F8988, paratype, T.S.; (21) UNE F8985, holotype, L.S. All from a limestone in the Coopers Creek Formation, Tyers R., Vict.

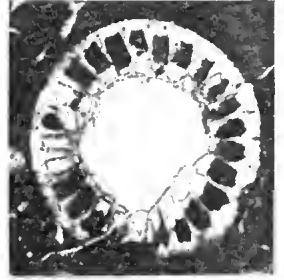




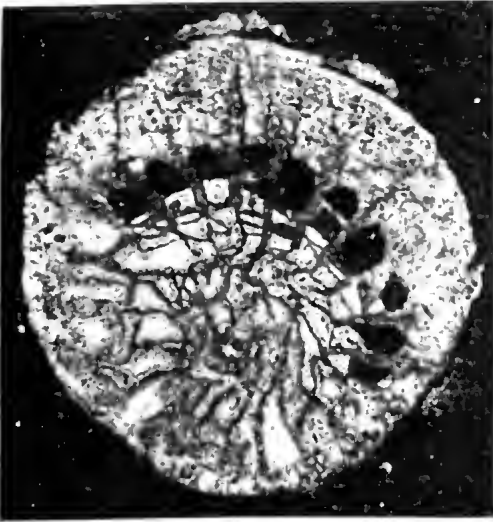
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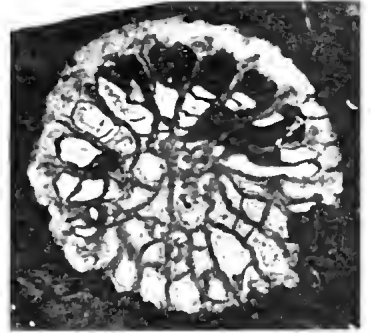
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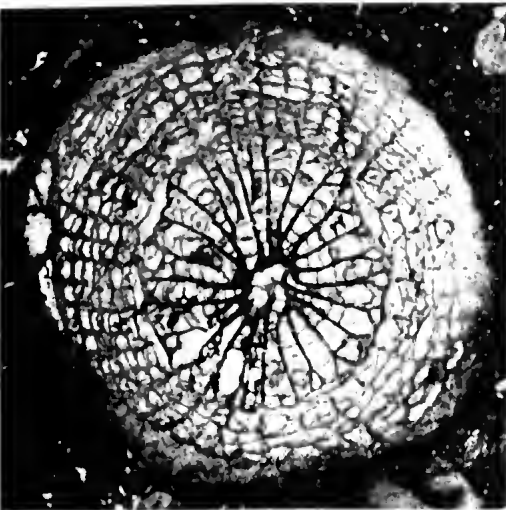
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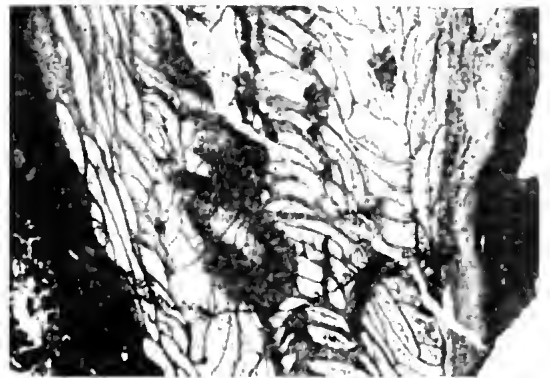
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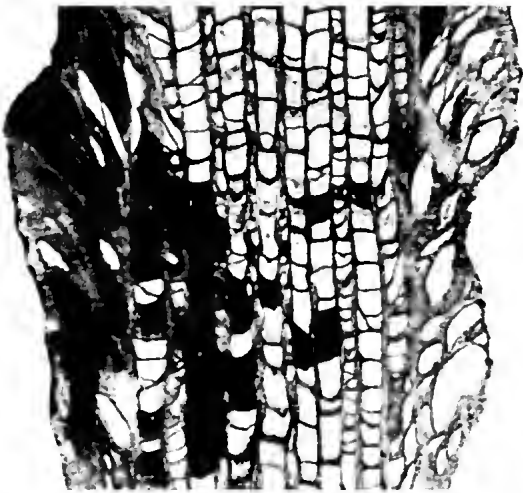
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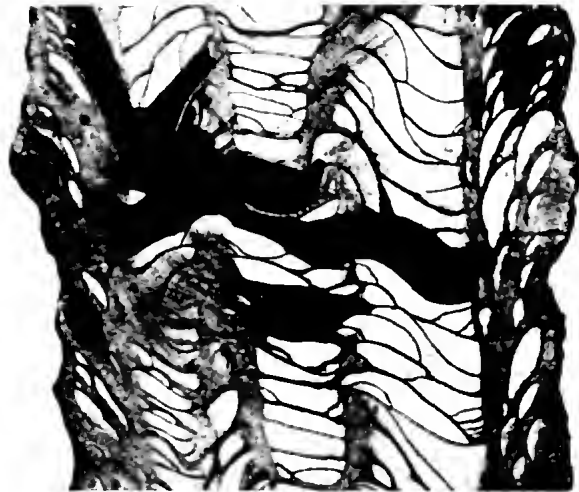
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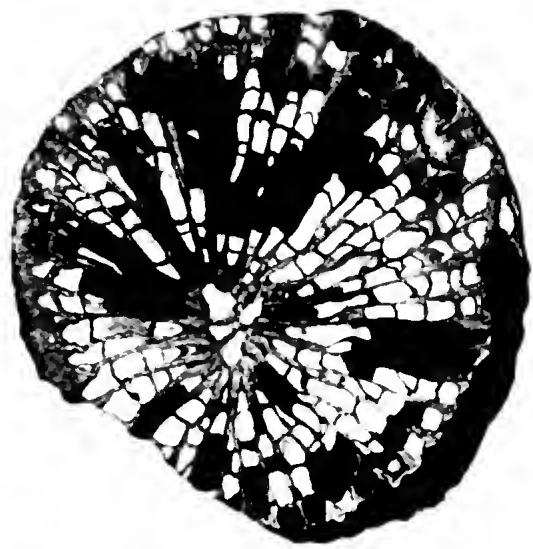
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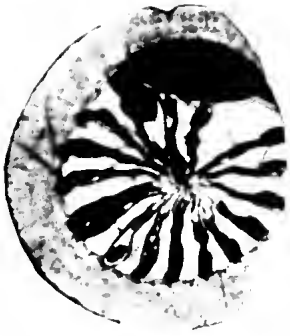
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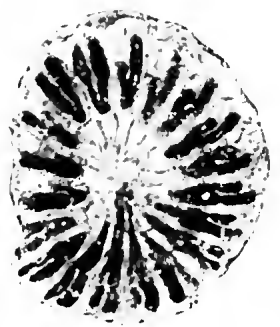
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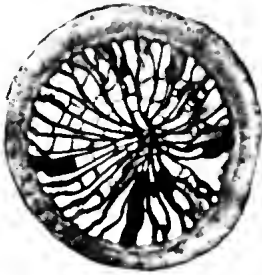
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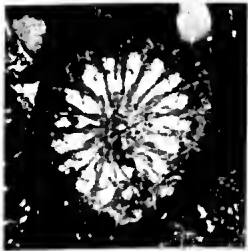
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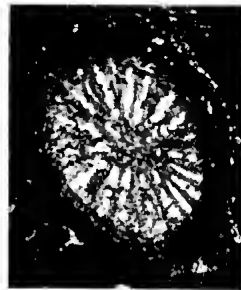
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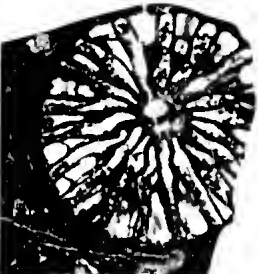
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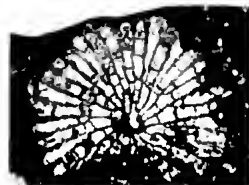
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# SOME EARLY TERTIARY MICROPLANKTON AND POLLEN GRAINS FROM A DEPOSIT NEAR STRAHAN, WESTERN TASMANIA

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## Abstract

Four new species of microplankton are described and seven species recorded from a Lower Tertiary deposit in western Tasmania. A few of the associated pollen types are figured and identified. The age of the deposit is discussed.

## Introduction

The sample examined, T27, was collected by Esso Exploration Australia, Inc. from the basal 15 ft  $\pm$  sandstone of a road cutting at the head of Long Bay, about 800 ft W of the Post Office at Strahan, western Tasmania. This sample consists mainly of a fine-grained sandstone, whitish in surface view, pale to dark brown when broken across, the depth of the colour depending upon the amount of the contained cuticular fragments and plant micro-fossils. Among this fine-grained material a few small, white, rounded, coarser-grained pieces bearing small quartz fragments attracted attention. Subsequent treatment of some of these revealed such an exceptionally high microplankton content that further investigation was almost entirely restricted to this type of matrix.

The holotypes and hypotypes are in the palaeontological collection of the National Museum of Victoria. Numbers prefaced by the letter P are registered numbers in that collection.

## Systematic Descriptions

### 1. MICROPLANKTON (I.C.C. & A.E.)

Class DINOPHYCEAE

Family DEFLANDREACEAE

Genus *Wetzeliiella* Eisenack 1938

*Wetzeliiella lineidentata* Deflandre & Cookson 1955

(Pl. 17, fig. 1, P24732)

*Wetzeliiella lineidentata* Deflandre & Cookson 1955, p. 253, Fig. 17, 18; Pl. 5, fig. 5.  
*Wetzeliiella lineidentata* Deflandre & Cookson, Cookson & Eisenack 1961, Pl. 1, fig. 7.

COMMENT: The specimen illustrated, the only one of its kind recovered from the Esso sample T27, appears to be close in most respects to the type from the Lower Tertiary deposit near Denmark, Western Australia, and those recorded by Cookson & Eisenack (1961) from deposits in the Rottne Island Bore, Western Australia, between 1480-1541 ft and 1575-1595 ft. The main differences are the sparsely toothed character of the margins of the Strahan example and the incon-

spieuousness of the 'rather prominent teeth' which delimit distinct fields in typical examples, especially the one from the Rottneet Bore illustrated by Cookson & Eisenack.

DIMENSIONS: *c.* 157  $\mu$  long, *c.* 152  $\mu$  broad, capsule  $72 \times 76 \mu$ .

***Wetzeliiella* cf. *lineidentata* Deflandre & Cookson 1955**

(Pl. 17, fig. 2, Fig. 1, P24733)

COMMENT: A single specimen which, while showing some of the characters of *W. lineidentata*, possesses others which appear to distinguish it from that species, has been recovered from the Esso sample T27. However, until more examples are found, a comparison rather than a direct association with *W. lineidentata* seems the more advisable procedure. The main features in which this specimen deviates from *W. lineidentata* are the stronger development of both apical and antapical horns, the development of only one antapical projection, the untoothed character of the margins and the presence of lines of prominent thickenings adjacent to the margins, on the edges of the girdle and, on the ventral surface, running obliquely from the ends of the girdle, upwards and downwards, towards the lateral margins.

DIMENSIONS: *c.* 172  $\mu$  long, 141  $\mu$  broad, incomplete, capsule  $71 \times 78 \mu$ .

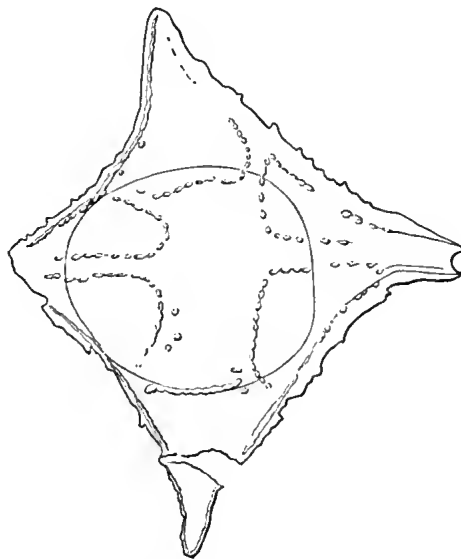


FIG. 1—*Wetzeliiella* cf. *lineidentata*, *c.* 400  $\times$ . Ventral surface, showing lines of thickenings.

***Wetzeliiella* cf. *articulata* Eisenack 1938**

(Pl. 17, fig. 3, 4, P24734, 24735)

*Wetzeliiella articulata* Eisenack 1938, p. 70, Fig. 4.

*Wetzeliiella articulata* Eisenack & Cookson 1956, p. 185, Pl. 2, fig. 6.

COMMENT: Two of the Strahan examples referable to *Wetzeliiella* agree in shape and general form with specimens of *W. articulata* from the Upper Eocene locality in

East Prussia. Both, however, differ from this species in the much sparser distribution of the appendages and their more broadly based characters. They also appear to be distinct from the specimen from the Victorian Dartmoor Formation referred by Cookson (1956) to *W. articulata*. More examples will be needed for the specific identification of such forms.

**DIMENSIONS:** Complete specimen *c.* 166  $\mu$  long, 138  $\mu$  broad; capsule 104  $\times$  90  $\mu$ .

***Wetzelicella homomorpha* Deflandre & Cookson 1955**

(Pl. 17, fig. 5, 6, P24736, P24737)

*Wetzelicella homomorpha* Deflandre & Cookson 1955, p. 254, Pl. 5, fig. 14, Fig. 17, 18.

**COMMENT:** Specimens which agree reasonably well with the examples of *W. homomorpha* from the type locality, the Upper Paleocene, Princetown Member of the Dilwyn Clay, Victoria, in size, shape, nature of the appendages, absence or inconspicuousness of the horns and the apparent absence of an internal body have been of regular occurrence in the Esso sample T27. However, evidence of an internal capsule and a circular to polygonal archeopyle, not previously recorded for this species, is present in the two figured examples.

**DIMENSIONS:** Overall length *c.* 76-104  $\mu$ , breadth *c.* 68-108  $\mu$ ; shell *c.* 56-96  $\mu$  long, *c.* 50-80  $\mu$  broad.

**Family HYSTRICHOSPHAERIDIACEAE**

**Genus *Homotryblum* Davey & Williams 1966**

***Homotryblum tasmaniense* n. sp.**

(Pl. 20, fig. 1-11; holotype fig. 1, 2, P24727, paratype fig. 4, 5, P24729)

**AGE and OCCURRENCE:** Paleocene: Esso Exploration Australia, Inc. Sample T27, Strahan, Tasmania.

**DESCRIPTION:** Shell spherical, relatively thin-walled, two-layered, coarsely granular to spinulose, with radially arranged tubular appendages which are open distally and vary considerably both in length and width. Usually those of a single specimen are of approximately the same length, but their width may vary quite considerably. The wall of the shell in the vicinity of the points of insertion of the appendages is smooth to finely granular, so that the base of each appendage is surrounded by a narrow circular area that contrasts distinctly with the general surface of the shell.

The shell opens by the separation of the 5-, or more rarely, 6-sided plates, each with a centrally placed appendage, into which the wall of one half of the shell (apical) becomes subdivided, the total number, approximately seven or eight, depending on the number of appendages originally present. These plates eventually separate from one another, either individually or occasionally in groups, so that an archeopyle embracing the whole equatorial region is formed.

**DIMENSIONS:** Holotype—overall diameter *c.* 83  $\mu$ , shell *c.* 55  $\mu$ , appendages 12-18  $\mu$ , 2-8  $\mu$  wide, 'funnel' 13-15  $\mu$  wide. Range—overall diameter *c.* 76-95  $\mu$ , shell *c.* 48-57  $\mu$ , appendages *c.* 5-24  $\mu$  long, *c.* 2-10  $\mu$  wide.

**COMMENT:** The reference of the Tasmanian form to the recently created genus *Homotryblum* rather than to the genus *Hystrichosphaeridium*, as originally intended, is based mainly on the type of archeopyle. An examination of Ehrenberg's type specimen of *H. tubiferum*, kindly lent by the Geological Department of the Humboldt University, Berlin, showed it to be relatively small and distinctly circum-

scribed in contrast to that of the epitraetal type which partly characterizes the genus *Homotryblum*.

Of the two species of *Homotryblum* at present established, *H. tenuispinosum* Davey & Williams 1966 from the London Clay seems to be the one to which *H. tasmaniense* most closely approaches. However it differs from the English species in the almost regular development of the smooth or very finely granular zones that surround the bases of the appendages and the complete separation of the sulcal plates. *H. tasmaniense* is very abundant in those of the Esso T27 matrices that are richest in microplankton.

#### Genus *Diphyes* Cookson 1965

##### *Diphyes colligerum* (Deflandre & Cookson) Cookson 1965

(Pl. 17, fig. 7, P24738)

*non Hystrichosphaeridium* sp. c. Cookson 1953, p. 155, Pl. 2, fig. 29, 30.

*Hystrichosphaeridium colligerum* Deflandre & Cookson 1955, p. 178, Pl. 7, fig. 3.

*Hystrichosphaeridium colligerum* Deflandre & Cookson, Cookson & Eisenack 1961, p. 42, Pl. 2, fig. 9.

*Baltisphaeridium colligerum* (Deflandre & Cookson) Downie & Sarjeant 1963, p. 91.

*Diphyes colligerum* Cookson 1965, p. 86, Pl. 2, fig. 29, 30.

COMMENT: Specimens referable to *D. colligerum* have occurred in low frequencies in the Strahan sample T27. The known range of this species in Victoria is a wide one (Cookson 1965), from Upper Cretaceous (probably Senonian) to Upper Eocene (Brown's Creek Greensand). *D. colligerum* has been recorded from a section of the Rottnest Island Bore, Western Australia (Cookson & Eisenack 1961, p. 42) which is believed to be of Paleocene age (Harris 1965, p. 100).

#### Genus *Cordosphaeridium* Eisenack 1963

##### *Cordosphaeridium inodes* (Klumpp) Eisenack 1963

(Pl. 19, fig. 12)

*Hystrichosphaeridium inodes* Klumpp 1953, p. 391, Pl. 18, figs. 1, 2.

*Hystrichosphaeridium inodes* Klumpp, Deflandre and Cookson 1955, p. 277, Pl. 8, fig. 7.

*Hystrichosphaeridium inodes* Klumpp, Gerlach 1961, p. 186, Pl. 28, figs. 4, 5.

*Cordosphaeridium inodes* (Klumpp) Eisenack 1963, p. 261, fig. 3.

COMMENT: Three examples which appear referable to *C. inodes* have been isolated from the Strahan sample T27. This species was recorded by Deflandre and Cookson in 1955 from two Victorian deposits, namely the Princetown Member of the Dilwyn Clay and the Birregurra Bore No. 1 at 760-761 and 959-960 ft, both of which are now classed as Palaeocene (Harris 1965).

#### Family AREOLIGERACEAE

##### Genus *Cyclonephelium* Deflandre & Cookson 1955

##### *Cyclonephelium variabile* n. sp.

(Pl. 19, fig. 9-11; holotype fig. 9, P24749)

AGE AND OCCURRENCE: Paleocene: Esso Exploration Australia, Inc. Sample T27, Strahan, Tasmania.

DESCRIPTION: Open shell roughly spherical in outline, with or without a short, blunt antapical prominence towards one side and a variable number of simple or branched appendages which vary considerably in both length and width, and may be either free or united with neighbouring ones. The appendages are most numerous near the margins of the shell, and almost entirely absent from a narrow central area on one side of the shell.



The shell opens by the detachment of the apical portion along an almost straight line.

**DIMENSIONS:** Holotype—overall diameter *c.* 109  $\mu$ , shell *c.* 75  $\mu$ , appendages *c.* 20-34  $\mu$  long. Range—overall diameter *c.* 85-120  $\mu$ , shell *c.* 60-90  $\mu$ , appendages 10-38  $\mu$  long.

**COMMENT:** *C. variabile*, as the specific name suggests, is extremely variable, and the limits and even generic placing of some of the examples are difficult to assess. *C. variabile* is clearly distinct from *C. retintextum* Cookson 1965 from certain Victorian Upper Cretaceous (probably Senonian) deposits and particularly the Paleocene Pebble Point Formation, in which both surfaces have clearly defined un-ornamented areas and all the appendages are looped.

#### FAMILY UNCERTAIN

Genus **Spinidinium** Cookson & Eisenack 1962

**Spinidinium esso** n. sp.

(Pl. 19, fig. 1-8; holotype, fig. 1, 2, P24753)

**AGE AND OCCURRENCE:** Paleocene: Esso Exploration Australia, Inc. Sample 27, Strahan, Tasmania.

**DESCRIPTION:** Shell small, somewhat flattened and oval in outline, with straight to convex sides, a relatively broad, circular, equatorial girdle with high ledges bearing short thin spines, a short blunt apical horn and a single sharply-pointed horn on the left-hand side of the antapex. Both surfaces of the shell are partially tabulated, the areas being delimited by short spines. On the ventral surface of the epitheca a small, roughly rectangular area outlined by small dot-like thickenings is usually clearly evident, and a relatively wide furrow-like region, delimited by small spines, is typically present in the hypotheca. An intercalary, trapezoidal archeopyle is developed on the dorsal surface of the epitheca.

In one specimen (Pl. 19, fig. 8) a relatively thin-walled cyst-like body, circular in outline, occupies approximately three-quarters of the cavity of the shell.

The wall of the shell, which is rather sparsely ornamented with pointed or knobbed spines, appears to consist of two closely opposed layers which separate from one another only at or near the bases of the horns, the position of the diaphragm varying in individual specimens. The apical horn tends to be straight-sided and its apex incurved; the antapical horn, which tapers to a sharp point, bears a few downwardly directed spines.

**DIMENSIONS:** Holotype—overall length 60  $\mu$ , width 46  $\mu$ , girdle 5  $\mu$  wide. Range—overall length *c.* 50-62  $\mu$ , width 40-52  $\mu$ , spines up to *c.* 3  $\mu$ .

**COMMENT:** *S. esso* differs from the Australian Cretaceous species *S. styloniferum* Cookson & Eisenack 1962 in the shape of the shell, the less numerous and finer spines, the presence of a simple form of tabulation and the shape of the archeopyle. It differs from the two American Paleocene species *S. densispinatum* and *S. microceratum* described by Stanley (1965) in the absence of a second antapical horn and, as far as can be judged from the illustrations of both species, the more regular and wider distribution of the spines.

Genus **Kenleyia** Cookson & Eisenack 1965

**Kenleyia lophophora** Cookson & Eisenack 1965

(Pl. 18, fig. 1-7, P24739-P24744)

*Kenleyia lophophora* Cookson & Eisenack 1965, p. 135, Pl. 5, fig. 7-10.

COMMENT: When the species *K. lophophora* was first described it was evident that a rather wide variation in the type and degree of fineness of the ornament and size and shape of the horns must be allowed for when future references to this species were being considered, a decision that, unfortunately, has been rendered more difficult by the unsatisfactory reproduction of the original illustrations. For these reasons we are illustrating several individual examples from the Strahan sample T27, which we feel may, with reasonable certainty, be associated with *K. lophophora* from the Dartmoor Formation in SW Victoria, an example of which is shown in Pl. 18, fig. 7.

Some of the Strahan examples differ from those of the Dartmoor Formation in (1) the more frequent absence of the 'tuft-like prominences' in the vicinity of the horns (Pl. 18, fig. 1, 7), (2) the greater variability in the length and shape of the horns, the apical horn sometimes being the longer of the two (Pl. 18, fig. 3) and (3) the degree of density and coarseness of the 'fibrilose' elements of the outer layer of the wall which, as in the two specimens shown in Pl. 18, fig. 4, 5, are sometimes relatively widely separated, broadly based and almost finely spine-like.

DIMENSIONS: Figured specimens *c.* 134-170  $\mu$  long, *c.* 82-123  $\mu$  broad.

#### INCERTAE SEDIS

Group ACRITARCHA Evitt

Sub-group SPHAEROMOPHITAE

Family LEIOSPHAERIDAE

Genus *Leiosphaeridia* Eisenack 1958

*Leiosphaeridia trematophora* n. sp.

(Pl. 19, fig. 13; holotype, fig. 13, P24752)

AGE AND OCCURRENCE: Paleocene: Esso Exploration Australia, Inc. Sample T27, Strahan, Tasmania; Upper Eocene: Brown's Creek, SW Victoria, carbonaceous clay above Greensand.

DESCRIPTION: Shell spherical, thin-walled, provided with a circular pylome, the rim of which is more or less thickened. A narrow, densely granular equatorial zone surrounds the shell.

DIMENSIONS: Holotype—*c.* 86  $\times$  74  $\mu$ , pylome *c.* 16  $\mu$ . Range—including the Brown's Creek examples *c.* 74-120  $\mu$ , pylome 15-22  $\mu$ .

COMMENTS: The specimens from the Strahan deposit are slightly thinner-walled than those from Brown's Creek. All the examples have been flattened and somewhat folded; however, the circular outline suggests that, originally, they were spherical.

Most of the known species of *Leiosphaeridia* are from Ordovician and Silurian deposits. One species, *L. similis* Cookson & Eisenack (1960), which is clearly distinguishable from *L. trematophora*, has been recorded from several Upper Jurassic deposits in Western Australia.

#### SUB-GROUP UNCERTAIN

Genus *Epicephalopyxis* Deflandre 1935

*Epicephalopyxis indentata* Deflandre & Cookson 1955

*Epicephalopyxis indentata* Deflandre & Cookson 1955, p. 292, Pl. 9, fig. 5-7; Fig. 56.

COMMENT: *E. indentata* occurs abundantly in the Esso Sample T27 from Strahan, Tasmania. Unfortunately, however, no further light has been thrown on the

nature and origin of this obscure form. In some specimens a fine median line crosses the flat surface.

Originally *E. indentata* was recorded from Victorian Paleocene deposits such as the Pebble Point Formation, the Upper part of the Dilwyn Clay, Nelson Bore at 3,894 ft and a few Lower Eocene deposits including one near Denmark, Western Australia.

*E. indentata* is so abundant in the Strahan sample, as well as in the SW Victorian deposits mentioned above, as to suggest the probability that it was a planktonic rather than an attached form as has been suggested for *E. adherens* from French Cretaceous flints (Deflandre 1935).

### Conclusion

It is clear that the microplankton assemblage recovered from the Strahan sample T27 provides definite information regarding the age of the deposit from which it was collected. The occurrence of such forms as *Wetzeliella homomorpha*, previously recorded from the Upper Paleocene Princetown Member of the Dilwyn Clay, Victoria; *W. lineidentata*, from the Lower Tertiary of Western Australia; *Kenleyia lophophora*, from the Paleocene Dartmoor Formation, Victoria; *Epicephalopyxis identata*, from several Paleocene deposits in Victoria, including the Pebble Point Formation, and the pollen type *Monosulcites prominatus* (*Baltisphaeridium taylori* Cookson & Eisenack 1965) from two New Zealand Lower Tertiary deposits (see p. 137) and the Paleocene Dartmoor Formation, Victoria, indicates that the age of the Strahan deposit, under consideration, is probably Paleocene, and younger than the Pebble Point Formation.

The pollen content (p. 137), as far as it has been studied, supports the suggested Paleocene age.

## 2. POLLEN AND SPORE CONTENT (I.C.C.)

Genus *Monosulcites* Cookson 1947 ex Couper 1953

*Monosulcites prominatus* McIntyre 1965

Pl. 18, fig. 8-12, P. 24745-24748)

*Monosulcites prominatus* McIntyre 1965, p. 214, fig. 33, 34.

*Baltisphaeridium taylori* Cookson & Eisenack 1965, p. 137, Pl. 16, fig. 9, 10.

COMMENT: In 1965 a microfossil present in small numbers in the Dartmoor Formation, Victoria, was referred by Cookson and Eisenack, to the microplankton genus *Baltisphaeridium*. Later, upon receipt of a paper by McIntyre (1965) on some New Zealand Tertiary pollen grains, it was found that an apparently comparable type had been previously described as a monosulcate pollen grain under the name *Monosulcites prominatus*. This fact is of particular interest in the present connection since a form similar to the one from the Dartmoor Formation has occurred regularly in the Esso T27 sample from Strahan, Tasmania. In all but one of the Strahan examples, as in those from the Dartmoor Formation and the two specimens of *M. prominatus* figured by McIntyre, the wall of one surface has been partially or completely missing. In this complete Strahan example (Pl. 18, fig. 8) one surface shows a relatively narrow, clearly defined, oval opening resembling a sulcus, thereby giving a clear indication that specimens of this type whether complete or incomplete, or circular or oval in outline, represent monosulcate pollen grains referable to the form genus *Monosulcites*.

A detailed study has shown that the exinous appendages are solid, variable in shape, usually narrowing from the base towards a bluntly pointed apex and occasionally, as in the New Zealand examples, slightly constricted at the point of

attachment. The exine is distinctly, though very finely, reticulate (Pl. 18, fig. 12), not granular as was stated in the earlier description (Cookson & Eisenack 1965, p. 137) and the muri are probably discretely baculate. It seems likely that the reticulum is below the surface, *i.e.* the wall of the whole object is tectate.

Examination of a specimen of *M. prominatus* recently generously supplied by Dr W. F. Harris of New Zealand has strengthened the belief that the Australian and New Zealand forms are generically, and probably specifically, identical.

**DIMENSIONS:** Complete example, overall c.  $64 \times 52 \mu$ , appendages c.  $5\text{--}9 \mu$  long.

A thorough examination of the pollen and spore content of the Esso Exploration Australia, Inc. sample T27 under consideration has not been possible at this time. However, a few of the more readily recognizable forms are recorded and illustrated in Plate 21 for comparison with similar types recently discussed by Harris (1965) in his detailed work on 'Basal Tertiary Microfloras from the Princetown Area, Victoria, Australia'.

The pollen and spore content of sample T27 has varied considerably in amount, according to the nature of the matrices treated, being lowest in the type with the richest microplankton content. The types considered and illustrated in Plate 21 are: *Cyathidites* sp. (fig. 1) of occasional occurrence; *Podocarpidites ellipticus* Cookson (fig. 2) numerous; *Phyllocladidites mawsoni* Cookson (fig. 3, 4) and *Microcachryidites antarcticus* Cookson (fig. 5), both of fairly frequent occurrence; *Tricolpites gillii* Cookson (fig. 6) occasional; *Tiliaepollenites notabilis* Harris (fig. 7) of regular occurrence in small numbers; *Polyporina fragilis* Harris (fig. 8) of regular occurrence; *Banksieidites* sp. (fig. 9) infrequent; cf. *Diporites* sp. Harris (fig. 10) infrequent; *Anacolosidites luteoides* Cookson & Pike (fig. 11) only the figured specimen observed; *Nothofagidites brachyspinulosa* (Cookson) and *N. emarcida* (Cookson) (fig. 12, 15) of regular occurrence but never numerous; *Proteacidites* cf. *dilwynensis* Harris (fig. 13) and *Proteacidites ornatus* Harris (fig. 14) in small numbers; '*Ephedra*' *notensis* Cookson 1957 of uncertain affinity in small numbers.

**COMMENT:** The occurrence of such forms as *Podocarpidites ellipticus*, *Tricolpites gillii*, *Tiliaepollenites notabilis* and '*Ephedra*' *notensis*, all of which appear, from previous investigations of Victorian Tertiary sediments, to be of Palaeocene age, supports the suggestion made earlier (p. 137) that the age of the Strahan sample is Paleocene and probably comparable with that of the upper portion of the Dilwyn Clay (Harris 1965, p. 2).

In this connection the apparent absence from the Strahan sample of two distinctive early Tertiary pollen types, namely *Triorites edwardsii* Cookson & Pike 1954 and *Proteacidites pachypolus* Cookson & Pike 1954, both of which were regarded by Cookson (1954) as of stratigraphical value, is of interest. Harris (*loc. cit.*) has recorded *T. edwardsii* from the Pebble Point Formation and *P. pachypolus* from the upper portion of the Dilwyn Clay, namely the Princetown Member. The association of *Tricolpites gillii* and '*Ephedra*' *notensis*, both of which are components of the Strahan microflora, with *Triorites edwardsii* in freshwater deposits near Launceston and Evandale in northern Tasmania, believed to be of Paleocene age (Gill 1962, p. 226), is of some significance.

#### Acknowledgements

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### Explanation of Plates

Unless otherwise stated the figures are of specimens from Esso Exploration Australia, Inc. Sample T27, Strahan, Tasmania.

#### PLATE 17

FIG. 1—*Wetzeliiella lineidentata* Deflandre & Cookson, (P24732)  $\times$  c. 256.

FIG. 2—*Wetzeliiella* cf. *lineidentata* (P24733)  $\times$  c. 460.

K

FIG. 3, 4—*Wetzelietta* cf. *articulata* Eisenack (P24734, 24735)  $\times$  c. 460.

FIG. 5, 6—*Wetzelietta homomorphia* Deflandre (P24736, 24737) showing archcopyle  $\times$  c. 650.

FIG. 7—*Diphyes colligerum* Cookson (P24738)  $\times$  c. 650.

#### PLATE 18

FIG. 1-5—*Kenleyia lophophora* Cookson & Eisenack (P24739-24743) showing wide morphological variation  $\times$  c. 650.

FIG. 6—*K. lophophora* showing two-layered character of wall  $\times$  c. 1,000.

FIG. 7—*K. lophophora* (P24744) from the type locality Dartmoor Formation, Victoria  $\times$  c. 550.

FIG. 8-12—*Monosulcites prominatus* McIntyre (P24745-24748), 8-10  $\times$  c. 650; 11, 12 an example from the Rivernook Member of Dilwyn Clay, Victoria; 11, exine in optical section  $\times$  c. 1,400; 12, reticulum in surface view  $\times$  c. 2,000.

#### PLATE 19

FIG. 1-8—*Spinidinium essoii* n.sp. 1, 2, (P24753) ventral and dorsal surfaces of holotype  $\times$  c. 650; 3, 4 (P24753, 24754) ventral surface of two examples  $\times$  c. 650; 5, dorsal surface (P24756)  $\times$  c. 650; 6, 7 (P24757) ventral surface of two examples  $\times$  c. 650; 8 (P24758) ventral surface of specimen containing a cyst-like body  $\times$  c. 650.

FIG. 9-11—*Cyclonephelium variabilis* n. sp. 9, holotype (P24749)  $\times$  c. 650; 10, 11, ventral surface of two specimens (P24750, 24751)  $\times$  c. 650.

FIG. 12—*Cordosphaeridium inodes* (Klumpp)  $\times$  c. 650.

FIG. 13—*Leiosphaeridia trematophora* n. sp. (P24752) holotype  $\times$  c. 650.

#### PLATE 20

All the figures are of *Homotryblum tasmaniense* n. sp. Fig. 1-9 are at a magnification of c. 650.

FIG. 1, 2—Two views of the holotype (P24727).

FIG. 3—Specimen showing delimitation and partial separation of plate-like areas on one surface (P24728).

FIG. 4, 5—Two views of the same specimen. 4, surface from which all but two of the plate-like areas have been completely removed (P24729).

FIG. 6—An example with short appendages.

FIG. 7—Specimen showing surface features and a particularly large appendage (P24727).

FIG. 8—Specimen showing complete removal of one surface, and detached plate-like area (P24730).

FIG. 9—Specimen showing an early stage in the delimitation of the plate-like areas (P24731).

FIG. 10—A portion of the shell wall showing the rod-like elements  $\times$  c. 1,500.

#### PLATE 21

All figures are at a magnification of c. 650.

FIG. 1—*Cyathidites* sp.

FIG. 2—*Podocarpidites ellipticus* Cookson.

FIG. 3, 4—*Phyllocladidites mawsoni* Cookson.

FIG. 5—*Microcachrydites antarcticus* Cookson.

FIG. 6—*Tricolpites gillii* Cookson.

FIG. 7—*Tiliaepollenites notabilis* Harris.

FIG. 8—*Polyporina fragilis* Harris.

FIG. 9—*Banksieidites* sp.

FIG. 10—cf. *Diporites* sp. Harris.

FIG. 11—*Anacolosidites luteoides* Cookson & Pike

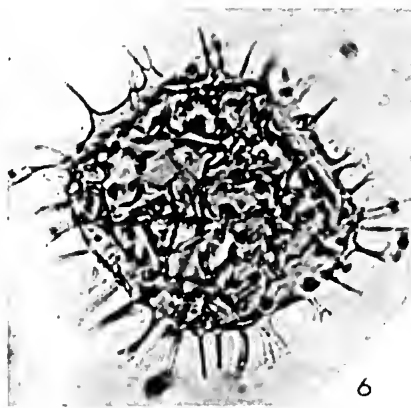
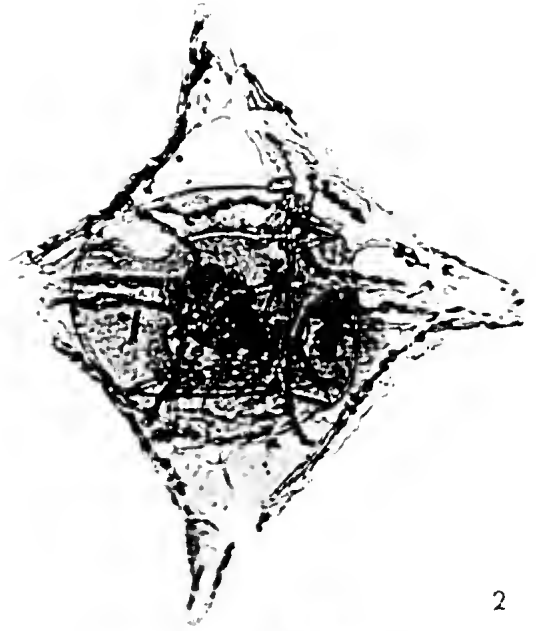
FIG. 12—*Nothofagidites brachyspinulosa* Cookson.

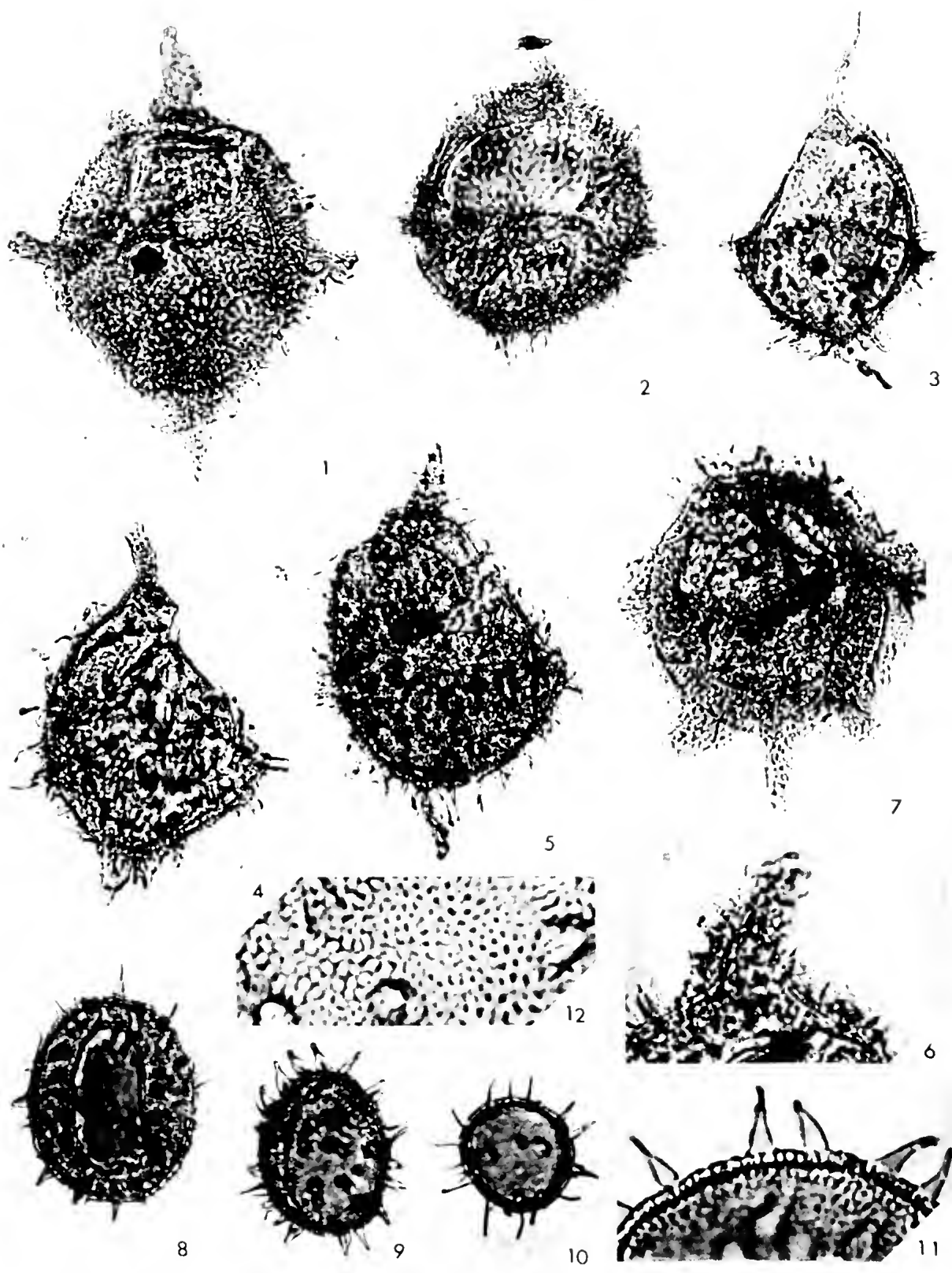
FIG. 13—*Proteacidites* cf. *dilwynensis* Harris.

FIG. 14—*Proteacidites ornatus* Harris.

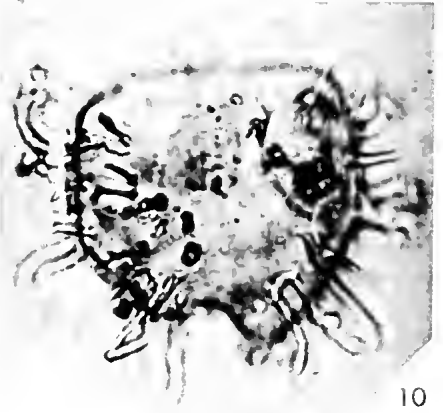
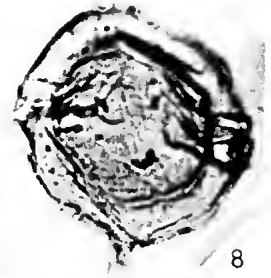
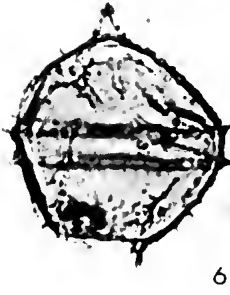
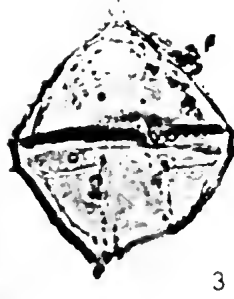
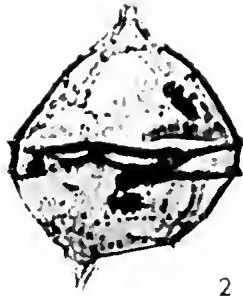
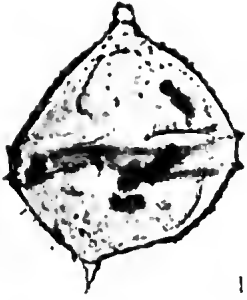
FIG. 15—*Nothofagidites emarcida* Cookson.

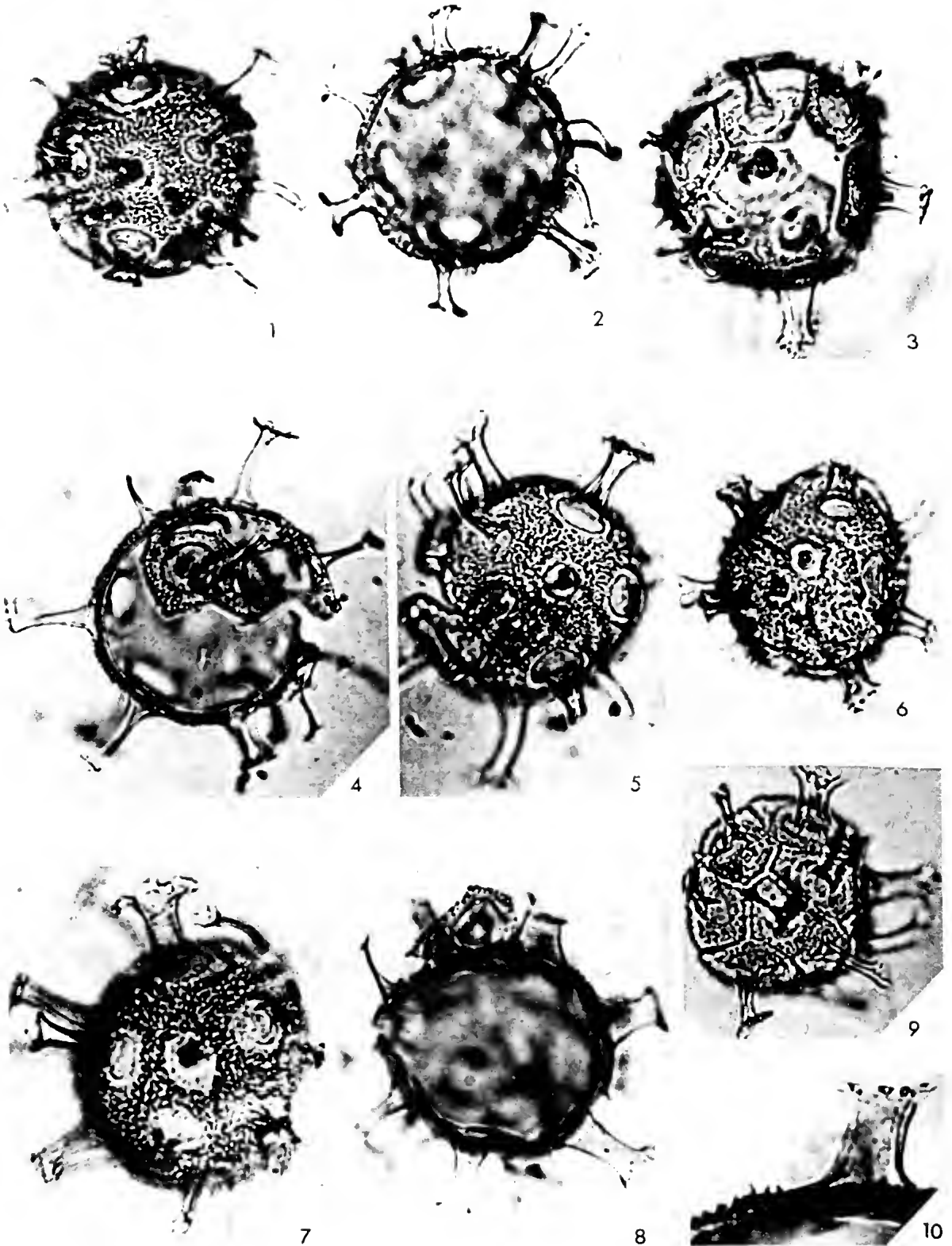
FIG. 16—*'Ephedra' notensis* Cookson.

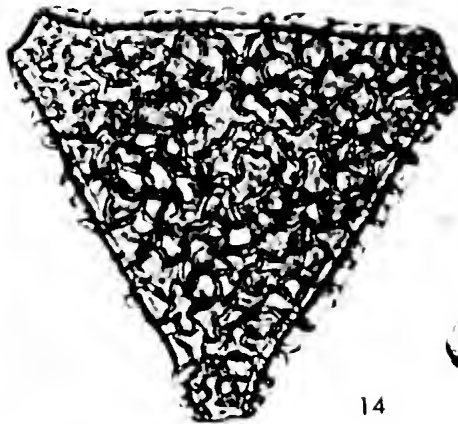
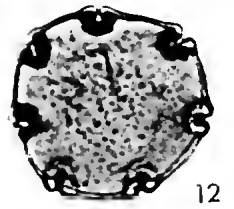
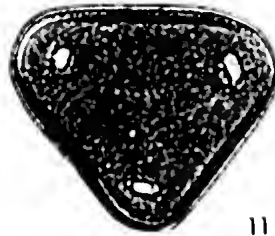
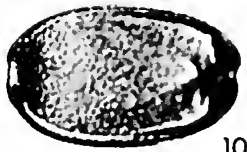
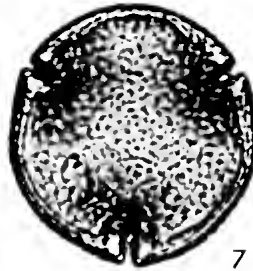
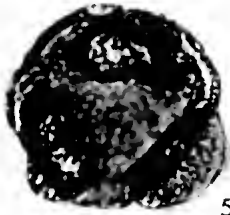
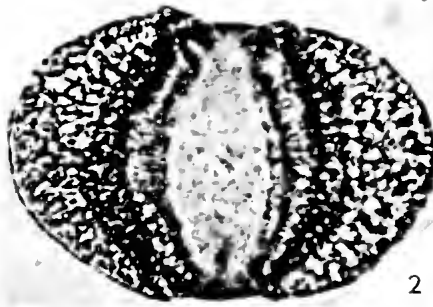
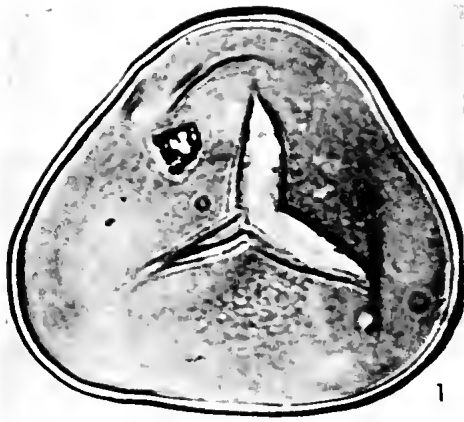














## ALLANETES, A NEW LOWER DEVONIAN CHONETID BRACHIOPOD GENUS

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### Abstract

*Allanetes* is proposed for a relatively large chonetid with a fold on the pedicle valve. It is based on *Allanetes neozelanica* sp. nov. from the Reefton beds (Emsian) of New Zealand. *Allanetes* is almost restricted to the Reefton brachiopod fauna, but probably is present in southeastern Australia if *Chonetes? foedus* Talent 1963 proves to belong. The new genus may be most closely related to the chonostrophids, considering the nature of the chilidial structures, but family assignment is uncertain.

### Introduction

The brachiopod fauna of the Reefton beds of New Zealand (Allan 1935, 1947) includes many large brachiopods that are generally well preserved as internal and external moulds. The assemblage is such a distinct one and comprises so many endemic or rare forms that it has been of particular interest over the years to students of Lower Devonian brachiopods. Among the particularly diagnostic elements are *Tanerhynchia* (a rhynchonellid), *Maoristrophia* (a strophomenacean), *Reeftonia* (a dalmanellid), *Reeftonella* (a smooth terebratuloid), and the large ribbed terebratuloid *Pleurothyrella venusta*. So far none of the provincial Reefton elements mentioned above has been found in North America or Europe. However, *Tanerhynchia* is known in the Lower Devonian Horliek Formation of Antaretica (Boucot, Johnson, and Doumani 1965). *Reeftonia* is known only from New Zealand and from Australia where it is represented by *Cariniferella alpha* Gill (Johnson and Talent 1967). *Reeftonella*, the smooth terebratuloid, is still unknown outside of New Zealand, and *Maoristrophia* occurs outside of New Zealand in Victoria, Tasmania, and Kazakhstan (Gill, Boucot, and Johnson 1966). *Pleurothyrella*, represented by *P. venusta*, appears to be an endemic form and is distinguished from other *Pleurothyrella* species by its bifurcating ribs (Boucot, Caster, Ives, and Talent 1963). The presently known occurrences of *Pleurothyrella* with simple ribs are in the Malvinokaffrie Province, including southern South America, the southern tip of South Africa, and the Antaretic (Boucot, Johnson, and Doumani 1965.)

In addition to the endemic and provincial forms, there are a few more-common brachiopod genera including a transverse acrospiriferoid of the *A. hercyniae* type (*Acrospirifer coxi* Allan 1947), which is widespread on a worldwide basis during early Emsian time and which serves in large part as the basis for a lower Emsian assignment of the Reefton beds yielding the new genus *Allanetes*. In view of the occurrence of the Reefton genera *Maoristrophia* and *Reeftonia* in Victoria and the probable occurrence there of *Allanetes*, represented by '*Chonetes*' *foedus* Talent, the Reefton brachiopod fauna may be accurately characterized as partly endemic and partly transitional between the Emsian fauna of the Malvinokaffrie Province and that of Victoria, south-eastern Australia.

The availability of considerable new fossiliferous material obtained by Boucot with the kind assistance of Professor Robin Allan during the austral summer of 1964-65 provided many specimens of the new chonetid genus *Allanetes*, proposed in this paper.

### Systematic Palaeontology

#### Superfamily CHONETACEA Bronn 1862

[*nom. transl.* Shrock and Twenhofel 1953 (*ex* Chonetidae Bronn 1862)]

#### FAMILY UNCERTAIN

#### Genus *Allanetes* gen. nov.

TYPE SPECIES: *A. neozelanica* Boucot and Johnson sp. nov.

DIAGNOSIS: Large concavo-convex chonetids with ventral fold and an ornament of coarse, rounded, bifurcating costae; ventral median septum high, blade-like; chilidial plates broadly disjunct.

SPECIES QUESTIONABLY ASSIGNED: *Chonetes? foedus* Talent (1963, p. 68, Pl. 37B, 38A). This species has the style of ribbing of *Allanetes* rather than *Parachonetes* and is sulcate, 'with pronounced differentiation between the main body of the shell and the weakly ornamented postero-lateral slopes' (Talent 1963, p. 68). The nature of the chilidial plates is not known.

#### *Allanetes neozelanica* sp. nov.

(Pl. 22, fig. 1-19)

MATERIAL: Specimens from USNM loc. 11000, Reefton beds, Reefton Subdivision, sheet S-38, 373, 23-2, Inangahua River section, 3½ miles southeast of Reefton on north side of Highway 7, South Island, New Zealand. 11000D, shales with *Allanetes*. 11000E, Creek bed argillites with *Allanetes*, *Maurispirifer*, and *Reeftonella*, etc. Collected by A. J. Boucot, 1965.

USNM loc. 11727, Reefton beds, lower band of argillite in creek bed. From the lowest observed fossiliferous band of the argillite which immediately underlies the main limestone; fossils from a small creek bed just off the side of the road, Reefton Subdivision, South Island, New Zealand. Collected by David Ives, loc. RS-001-RS013, 1963.

The illustrated specimens are deposited in the University of Canterbury Museum, Christchurch, New Zealand.

EXTERNAL FORM: The valves commonly reach a relatively large size for Siluro-Devonian chonetids and generally are a little wider than long. The largest specimens usually attain a maximum dimension of 25-30 mm along the hinge line. Accurate measurements of the original shell dimensions are not obtainable because of distortion and inadequate preservation. In lateral profile they are moderately concavo-convex delimiting a small body cavity. The hinge line is long and straight, but generally less than the maximum width of the valves slightly posterior to midlength. The cardinal angles are obtuse and evenly rounded, no development of mucronation being seen on any of the available specimens. Medially on the pedicle valve there is a broad rounded fold that may become pronounced anteriorly and there is a corresponding broad, shallow sulcus medially in the brachial valve.

EXTERNAL ORNAMENT: The external ornament consists of relatively strong rounded radial costae that increase in number anteriorly by bifurcation on the pedicle valve and by intercalation on the brachial valve. The costae are separated

by deep rounded interspaces of approximately the same width as adjoining costae. The costae that reach the posterior margin of the valve emanate from the beak and none originate along the hinge line. 10 mm anterior to the hinge line, there are commonly 5 or 6 costae in the medial region of brachial valves in a space of 5 mm.

**POSTERIOR STRUCTURES:** A few spine bases are preserved along the hinge line of the pedicle valve and they prove to be fairly prominent small conical projections. Commonly there are two or three spine bases on each side of the hinge line. The interarea of the pedicle valve is well developed, flat, subtriangular, and orthocline. The delthyrium is covered apically by a posteriorly convex pseudodeltidium with a slightly concave dorsal edge. The interarea of the brachial valve is long, low, flat, and steeply anacline or hypercline. The chilidial plates are completely disjunct, discrete plates lying lateral to the base of the cardinal process lobes medial to the sockets, and connecting with the posterior faces of the inner socket ridges.

**INTERIOR OF PEDICLE VALVE.** The hinge teeth are sub-semicircular lobes projecting anteriorly from the edge of the interarea. Internally the teeth are thickened by divergent rounded ridges that lie beneath the interarea, but the teeth are not connected with the base of the valve by dental lamellae. Posteriorly there is a short but very high, plate-like median septum that extends anteriorly approximately to the middle of the adductor muscle scars. The adductor muscle scars form an elongate pyriform impression that is very faintly defined and may be bounded posterolaterally by broad, low, muscle bounding ridges. The diductor impression is broad and fan-shaped, anteriorly flabellate, but poorly impressed everywhere except along its posterolateral extremities. The remainder of the interior, lateral and anterior to the muscle impressions, is papillose.

**INTERIOR OF BRACHIAL VALVE:** The cardinalia consist of a pair of cardinal process lobes, chilidial plates, and inner socket ridges. The chilidial plates, being broadly discrete and situated away from the apex of the notothyrium, are essentially interior structures, but are described above. The outer socket ridges are faint and consist essentially of slight internal projections of the edge of the interarea. The inner socket ridges are strong, broadly divergent, rounded ridges that support a pair of cardinal process lobes medially. There is a broad, shallow pit or alveolus on small specimens, adjacent to the medial junction of the inner socket ridges. The cardinal process lobes are a pair of short plates that face more or less posteriorly on small specimens, meeting dorsomedially, but diverging slightly toward the pedicle valve so as to have an external appearance of an inverted V when viewed from the posterior. In large specimens the chilidial plates are vestigial, the cardinal process lobes become more clearly a pair of distinct plates, and the whole notothyrial area is thickened, forming a triangular platform at the expense of the broad alveolus present in very small specimens. There is a short divergent pair of anderidia and a long, low median septum that originates slightly anterior to the notothyrial platform. The cardinal process lobes project posteroventrally. The interior is pustulose except in the area of the muscle impressions.

**RELATIONS:** Externally the size, convexity, and the coarse bifurcating costae give *Allanetes* some resemblance to *Parachonetes*, recently proposed by Johnson (1966, p. 365). However, *Parachonetes* does not develop a ventral fold. In addition, lateral ribs of *Parachonetes* originate along the hinge line while in *Allanetes* they originate medially and parallel the hinge line. Internally, *Allanetes* differs even more strongly from *Parachonetes*. The new genus lacks the well developed alveolus of *Parachonetes*, but instead has a pair of pillar-like cardinal process lobes erected on an elevated triangular platform. The chilidial plates of *Parachonetes* appear to be

very small and apically situated while the chilidial plates of *Allanetes* are broadly disjunct and essentially internally situated. *Allanetes* differs from *Eccentricosta* Berdan (1963) on most of the points discussed above for *Parachonetes*. In addition, *Eccentricosta* has the split ventral septum commonly seen in *Protochonetes*.

The older genera *Protochonetes* and *Strophochonetes* are both small, generally more nearly flat, and have much finer ribs. Internally, neither *Protochonetes* nor *Strophochonetes* has cardinalia that suggest any close relation to *Allanetes*. *Chonetes*, as strictly interpreted (see Muir-Wood 1962, p. 35-40), is commonly flatter, has finer costae, and lacks external trilobation. Internally, *Chonetes* bears different cardinalia, lacks the widely disjunct chilidial plates of *Allanetes*, and bears accessory septa-structures that are not developed in *Allanetes*.

*Allanetes*, in some respects at least, can be compared with the chonostrophiids—*Chonostrophia*, *Chonostrophiella* Boucot and Amsden (1964), and *Notiochonetes* Muir-Wood (1962). All of these have the unusual broadly disjunct chilidial plates situated lateral to pillar-like cardinal process lobes. The shape and external ornament of the three chonostrophiid genera, however, is very different from that seen in *Allanetes*. The chonostrophiids are typically nearly planar shells with *Chonostrophia* and *Chonostrophiella* being faintly convexo-concave compared to *Notiochonetes* which is gently concavo-convex. The external radial ornament of all three is very fine, thus the considerable differences in shape and external ornament suggest something less than close association between them and *Allanetes*, and for this reason the ancestor of *Allanetes* must be regarded as uncertain.

#### Acknowledgements

The writers are indebted to Professor Robin Allan, University of Canterbury, Christchurch, New Zealand for taking Boucot to the collecting site of *Allanetes* during the austral summer of 1964-65. The writers' work in Pasadena has been done under a grant from the National Science Foundation, No. GP-3743. We designate the new chonetid genus *Allanetes* in recognition of Professor Allan's almost singlehanded efforts over a period of more than thirty years to make known the Early Devonian fossils of the Reefton area.

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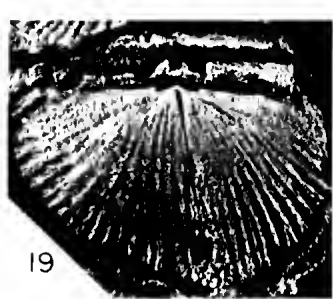
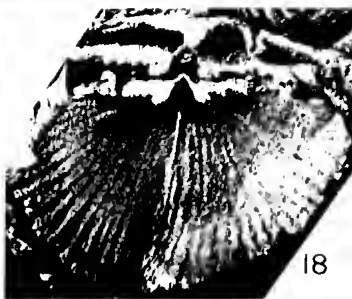
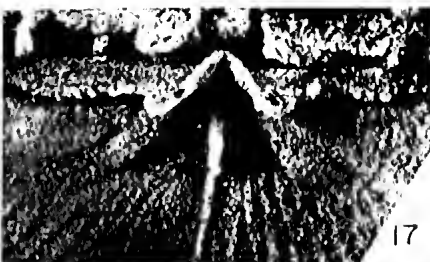
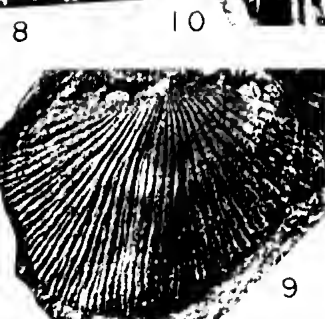
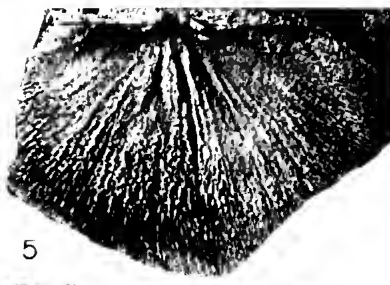
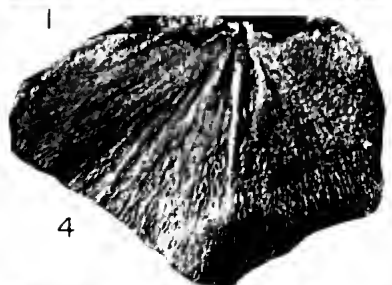


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### Explanation of Plate 22

- FIGS. 1-19.—*Allanetes neozelanica* gen. et sp. nov. Reefton beds (Lower Emsian) Sheet S-38, 373, 23-3, Inangahua River section, 3½ miles SE of Reefton on north side of highway 7, Reefton Subdivision, New Zealand. USNM Locality 11000. Collector A. J. Boucot, 1965. Figs. 1-8, 10-19 loc. 11000D. fig. 9, loc. 11000E. 1-3. Internal mould of brachial valve and rubber impression  $\times 2$ , and rubber impression  $\times 4$ , UCM 451; 4, 5. Rubber impression and internal mould of brachial valve  $\times 2$ , UCM 452; 6-8. Posterior and interior views of rubber impression  $\times 10$  and internal mould  $\times 5$ , UCM 458; 9. Rubber impression of external mould of pedicle valve  $\times 2$ , impression of UCM 454; 10. Rubber impression of external mould of brachial valve and interarea of pedicle valve  $\times 2$ , UCM 455; 11, 12. Rubber impression of internal mould of pedicle valve and posterior view of internal mould  $\times 1.5$ , UCM 456; 13. Posterior view of internal mould of pedicle valve  $\times 2$ , UCM 457; 14. Oblique view of rubber replica of ventral interior,  $\times 4$ , impression of UCM 457; 15, 16. Posterior view of external mould of brachial valve and dorsal view of rubber impression  $\times 2$ , UCM 453, counterpart of specimen in fig. 5; 17-19. Interior view  $\times 5$  and  $\times 2$  of rubber impression and internal mould of pedicle valve  $\times 2$ , UCM 459.







## STRUCTURES IN THE ORDOVICIAN ROCKS OF VICTORIA

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### Abstract

Microscopic, mesoscopic and macroscopic structures imposed on the Ordovician rocks of Victoria are described. Deposition and folding were pene-contemporaneous, deposition taking place in rapidly subsiding troughs. It is believed that deposition was restricted for the most part to two main troughs: the Western Trough and the Eastern Trough. The former virtually ceased to exist at the close of the Lower Ordovician; the latter began its development at that stage and was effectively destroyed at the end of the Upper Ordovician. Two tectonic axes: the Heathcote, and the Dookie-Tatong, are regarded as being of considerable significance, and a third axis, represented by the Muckleford Fault, also played a major role in the tectonic history of the Ordovician rocks.

### Introduction

As a result of a series of detailed studies of structures in the Ordovician rocks of Victoria, it became apparent that both the similarities and differences in the styles and the geometry of the structural elements provided significant data for the assessment of the tectonic development of these rocks. This paper is a systematic description and analysis of the structures studied: microscopic, mesoscopic and macroscopic structures have all been considered.

Microscopic structure means one which can be seen only under the microscope and includes those elements which can be determined by petrofabrie analysis alone. Mesoscopic structures are those to be observed in a single continuous exposure, or handspecimen, and include bedding, folds, foliations, lineations and joints. Macroscopic structures are those which can be determined only by the synthesis of mesoscopic data and lithological and stratigraphic mapping.

Fig. 1 shows the distribution of Ordovician rocks in Victoria. Stratigraphically and structurally, as well as geographically, the rocks fall into two units: those of eastern Victoria which are mainly of Upper Ordovician age and which, in many places, have suffered superposed deformation; the second unit comprises the Ordovician rocks of western Victoria, which are, for the most part, Lower Ordovician, and which, except very locally, have been subjected to a single folding deformation. In both far eastern and far western Victoria, the sediments have been regionally metamorphosed. The eastern metamorphic belt is the more prominent; in western Victoria the schists and gneisses are exposed only in valleys where erosion has removed younger rocks.

Due largely to the work of W. J. Harris, D. E. Thomas, and the Geological Survey of Victoria, the regional structure of the eastern sector of the Western Trough, including the form of macroscopic folds, is well known. Because of mining activity in this region the mesoscopic structural elements have also been studied in some detail, but published systematic descriptions are few (Hills & Thomas 1945; Beavis 1964). In spite of detailed mapping by J. G. Easton, in north-eastern Victoria, virtually nothing is known of the structure of this region, due largely to the apparently uniform lithology and the almost completely unfossiliferous nature of

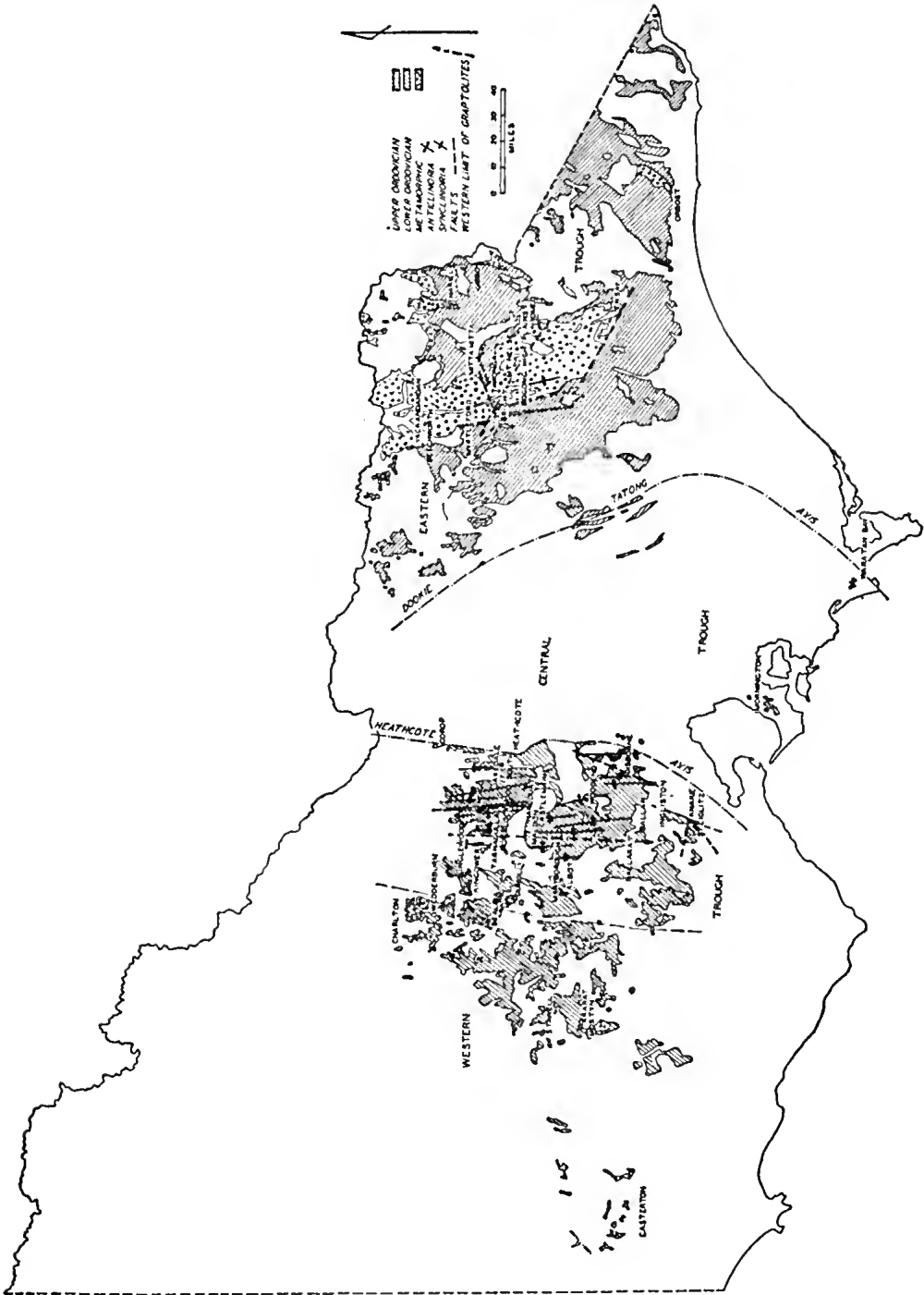


FIG. 1—Distribution of Ordovician rocks in Victoria. This figure shows the localities mentioned in the text.

the rocks. In far western Victoria, the only publications relating to structure are those of Wells (1956) and Clappison (1960). Here, as in the eastern part of the State, macroscopic structure can often only be surmised. In 1939, D. E. Thomas described the broad structural features of the Lower Palaeozoic rocks of Victoria. Since that time, with the exception of some important papers on the structure of the Silurian rocks, little of significance has been added. Thomas (*op. cit.*) noted that the most westerly exposures of Ordovician rocks, the precise stratigraphic position of which is known, are those of Bealiba, Goldsborough, Tarnagulla, Dunolly and Maryborough. The assumed Ordovician rocks to the W. are unfossiliferous and since at the localities noted, the fossils are all Lancefieldian, the possibility that the sediments to the W. may be Cambrian cannot be excluded. In the eastern part of the Western Trough the structure and stratigraphy are well known except for the area NW. of the Harcourt Batholith, although the work of the Geological Survey since 1939 (as yet unpublished) may have elucidated this. S. and N. of the Harcourt Batholith the structure is known in great detail (see Fig. 2).

Harris and Thomas have described the macroscopic folds in the graptolite-bearing sediments as 'domes' and 'basins', i.e. relatively open, broad anticlinoria and synclinoria. Thomas now uses the terms 'brachyantelinoria' and 'brachysynclinoria' which seem preferable. Within these macrofolds, the sediments are more or less sharply folded, with average dip of bedding  $70^\circ$  and the average distance between hinges of mesoscopic folds 250 to 300 ft. Regional reversal of plunge and the adjunction of folds with plunge in opposing directions have the effect of an anticlinorium giving way to a synclinorium, e.g. the Pyrete anticlinorium to the Woodend synclinorium, the Riddell synclinorium to the Axedale anticlinorium and the Lauriston anticlinorium to the Strathfieldsay synclinorium. Effectively, there is an *en echelon* pattern of anticlinoria and synclinoria.

With the possibility of stratigraphic and lithological mapping outside the fossiliferous belt only slight, macroscopic structure can be only surmised. In NE. Victoria, e.g. the Kiewa Anticline has been postulated (Beavis 1962a), with evidence to suggest that while it is comparable to the anticlinoria of the Western Trough, it tends more to be a long open structure lacking the typical hinge line characteristics (i.e. reversal of plunge).

Hills and Thomas (1953) envisaged deposition in a large single basin which, in the early Ordovician, was deepest in the western half of the state, while in the eastern half, deposition did not begin until the Upper Ordovician. They considered that emergence first occurred from this basin in the E., but that the basin as a whole was not destroyed until the Mid-Devonian Tabberabberan Orogeny. Their conclusion that the effects of the Benambran and Bowning Orogenies were confined to eastern Victoria was supported by this writer (Beavis 1962a), but Hills and Thomas concluded that 'minor dislocatory movements, superimposed on the broad sinking of the trough, were operative virtually continuously, the "orogenies" being culminations of such movements'.

Large scale faulting has disrupted the Ordovician rocks; some, at least, of the faults are very ancient structures and may date from the Ordovician. Again, the faults for the most part are known only where detailed stratigraphic mapping has been possible: the faults have often been inferred from the absence of graptolite zones. Many of the more important faults are meridional, e.g. the West Kiewa Thrust, the Muckleford Fault and the Whitelaw Fault. Others, such as the Hanover, Djerriwarrah and Tawonga Faults, trend north-easterly. Only a few trend E.-W. Most of the faults are high-angle thrusts, a few arc wrench faults. Later renewed

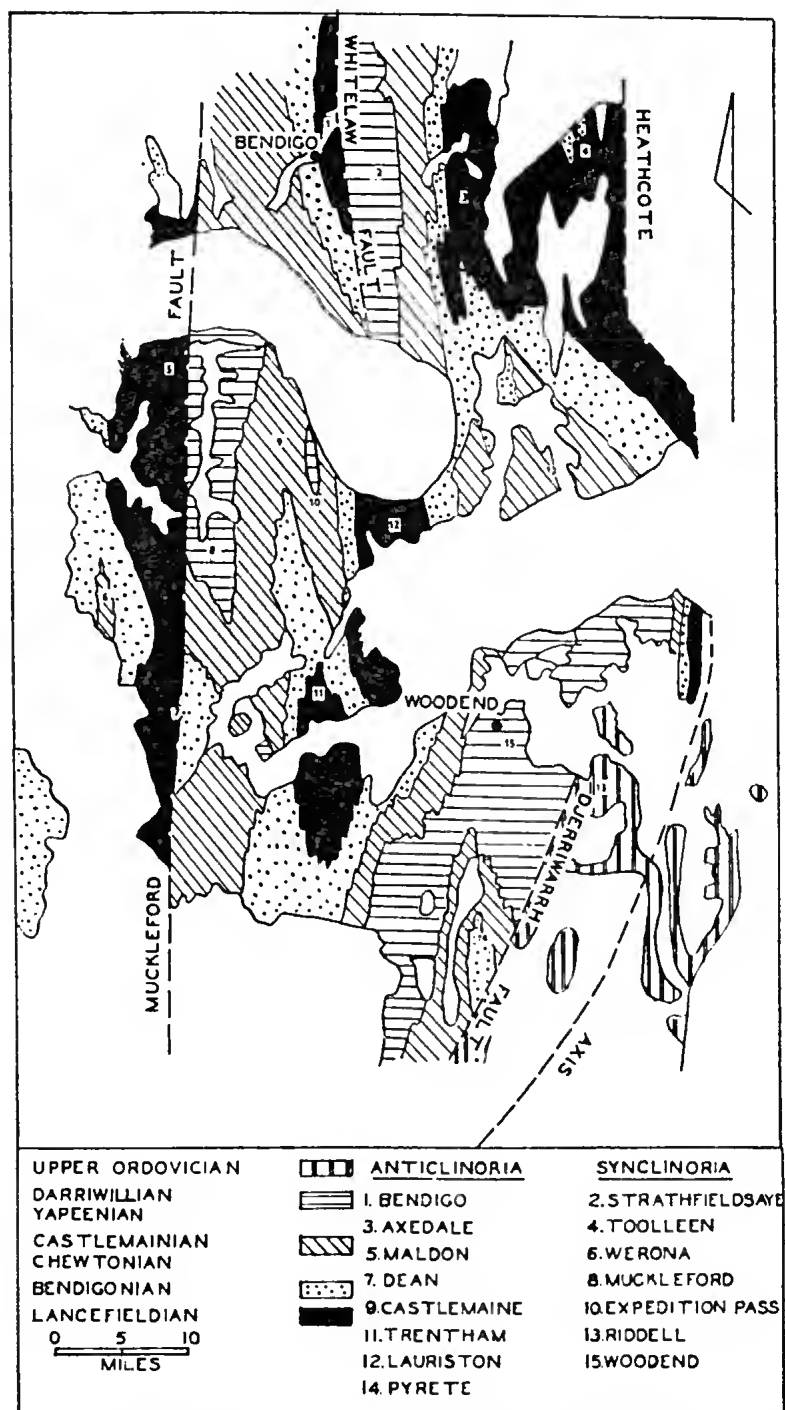


FIG. 2—Structure of the eastern sector of the Western Trough; after D. E. Thomas.



movement often differed from the original, e.g. the Tawonga Fault originated as a dextral wrench, but the late Cainozoic movement was low-angle thrusting (Beavis 1960); in Central Victoria, Cainozoic normal faulting took place along Palaeozoic high-angle thrusts. In some cases, *en echelon* fault systems occur, e.g. in North East Victoria, the Tawonga, Granite Flat, and Cudgewa Faults form such a system. The time and structural relationships of faulting and folding are sometimes clear, but are more often obscure. The relationship between folding and intrusive activity is often quite intimate. It has been shown, e.g. that cleavages and small folds have been superposed on sediments about the Harcourt and Beechworth batholiths (Beavis 1964b, 1964c), while there has been a suggestion that the macroscopic folds may have influenced the locus of batholith intrusion (Stewart 1962; Beavis 1964b). The plutons intrusive into the Ordovician rocks vary in age relative to the folding, and any influence of, or on, the folding would have been controlled by the age relationship.

A further factor which influenced the structure of the Ordovician rocks was the nature of the sediments. This is particularly true for the mesoscopic structures. Variation in composition and texture of the sediments resulted in variations in the reaction of the rocks to stresses. Throughout the state, the rocks are alternating greywackes and slates and their metamorphic equivalents. Often the beds are one to two ft thick, but relatively thick beds of greywackes and slate are not uncommon. The condition of the rocks during deformation, and their tectonic environment, were additionally of considerable importance, particularly in the development of superposed structures.

This paper describes and discusses the microscopic, mesoscopic and macroscopic structures, firstly for the western sector of the state, W. of the Heathcote Axis, and secondly for the eastern sector, E. of the Dookie-Tatong Axis. Finally the data are discussed.

In a project of this kind, many people have contributed, but special reference should be made to my wife, who carefully prepared many of the figures; to Dr D. E. Thomas, Professor E. S. Hills and Dr O. P. Singleton, who have over a period of years discussed many aspects with me, and to the late Dr W. J. Harris who first introduced me to many of the fascinating problems of Ordovician geology in this state.

### The Ordovician Rocks West of the Heathcote Axis

#### MICROSCOPIC STRUCTURES

With the exception of the coarse greywackes, the crystalline schists and rare quartzites, the Ordovician rocks in Victoria do not lend themselves readily to petrofabric studies and few such analyses have been made. Quartz and mica sub-fabrics of the crystalline Casterton Schists were described by Wells (1956), quartz sub-fabrics of greywackes in the Chewton district by the writer (Beavis 1964b). Usually the mica fabrics show the micas lying in two *s* planes: bedding, and foliation (*aB*). Symmetry is near monoclinic to triclinic. The quartz fabrics have a symmetry from near orthorhombic, to monoclinic or triclinic. The actual relationship of quartz orientation to mesoscopic fabrics is not always clear, and lacking detail given by axial distribution analyses, the main value of the quartz fabrics lies in their symmetry.

Dimensional orientation of quartz grains in quartzites, sufficient to impart a foliation to these rocks, is rare. It is seen, however, in some cleaved greywackes. Any such dimensional orientation is visible only microscopically: the rarity of this structure suggests that the deforming stresses were not sufficiently strong or that the

confining pressures were too low for such an orientation to be produced. Axial distribution analyses of quartzites in the Bendigo district (Beavis 1964b) showed that direction groups existed which defined conjugate planes not visible even microscopically. This method has shown the presence of these planes in quartzites wherever examined from this part of the state.

Pressure fringes on hard, relatively large mineral inclusions in slate have been ascribed by Mugge (1933) to rotation of the hard crystals between cleavage planes in the deforming slate. The presence of these fringes can then be regarded as evidence of rotation as one effective mechanism in deformation. Pressure fringes on pyrite in slates have been recorded by Hills (1963) from Bendigo, but they are common in slates throughout the state. In an example from Corop, on the Heathcote axis, the fringes consist of muscovite, calcite and quartz, also showing a preferred dimensional orientation, with kink zones that infrequently are present in the calcite and muscovite. The fringes and the hard porphyroblasts are usually bounded by fine shears.

### MESOSCOPIC STRUCTURES

#### BEDDING AND LITHOLOGICAL LAYERING

Beds in the Ordovician rocks range from laminac 1 mm thick to massive sandstones and slates over 10 ft thick. The average thickness of beds, however, is between 1 and 2 ft. Bedding is a prominent feature of the laminated greywackes, but in non-laminated greywackes, quartzites and thick slates, it may be obscure and recognizable only after careful examination for slight colour variations. The nature of the graded bedding, characteristic of the greywackes, has been described

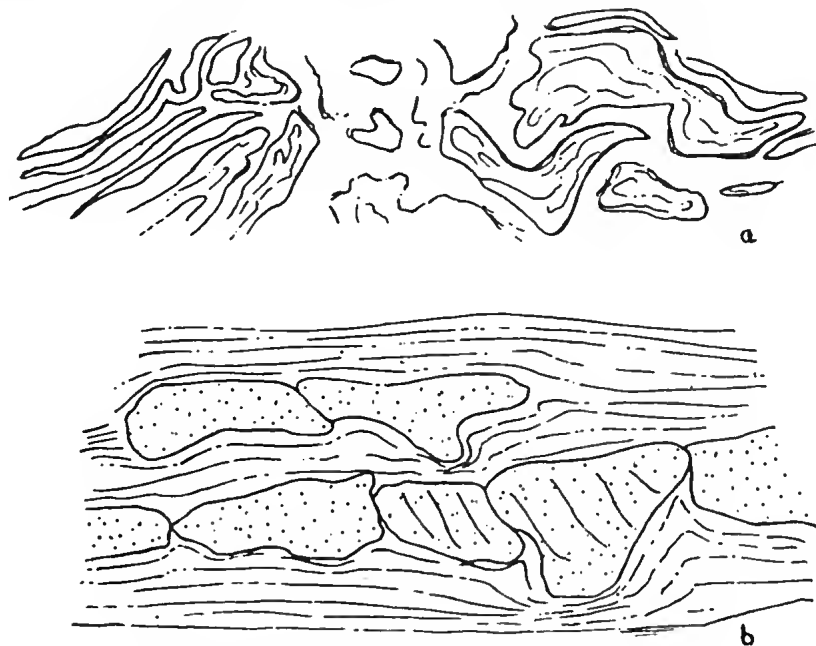


FIG. 3—Primary bedding features in greywackes.

- a. Convoluted bedding in fine greywacke, Steiglitz.
- b. Pseudo-boudinage in siltstone, Ingliston. Fig.  $\times \frac{1}{2}$ .

by Hills and Thomas (1953) who pointed out that, while graded beds are typical, sharply bounded non-graded beds also occur. Two types of gradation are found: simple and oscillatory. The latter is of particular value in the study of cleavages and small-scale folds.

Fine current bedding is often present in the sandstones, the upper surfaces of which may have fine ripple marks. Primary load casts, intraformational deformation and convoluted bedding point to the high moisture content and plasticity of the sediments at deposition. In places a pseudo-boudinage has been formed during deposition (Fig. 3b).

One of the most significant features of bedding is the lack of persistence of a particular bed. Even quite distinctive beds can rarely be traced for more than a few chains. Bedding as a recognizable structure persists into quite high-grade metamorphic rocks, and it is possible in some instances, at least, to relate lithological layering in high-grade schists and gneisses to original bedding. In the metamorphosed Ordovician rocks of western Victoria no general rule can be formulated relating lithological layering to original bedding, and each case must be individually assessed. For example in the Casterton and Ararat schists, the layering usually clearly represents bedding, with the original gradation preserved and readily recognizable. This gradation may be either simple or oscillatory. However, in both of these areas, some of the layering is of doubtful origin and some is clearly due to metamorphic segregation. Quartz-albite layers are lenticular in a predominantly micaceous matrix, there is no evidence of gradation, and petrographic evidence suggests an original pelitic sediment. In this case, the lithological layering is grossly discordant to that, which can with certainty, be correlated with bedding.

In the Charlton district, the schists in part have a distinct lithological layering which has resulted from transposition of beds, metamorphic segregation having played only a minor role. Here, original bedding lamination has been largely obscured (Fig. 4). Again, however, much of the layering in the schists of this district is due to original bedding.



FIG. 4—Schist showing transposition on *s* planes, Charlton.  $\times \frac{1}{10}$ .

#### FRACTURE CLEAVAGE

The distinction between fracture cleavage and strain-slip cleavage is not always clear, and frequently the terms have been interchanged. The term 'fracture cleavage' was introduced by C. K. Leith (1905, 1923) who also equated it with some forms of strain-slip cleavage. Here it is regarded as a series of more or less closely spaced fractures; movements producing the cleavage have not produced any preferred orientation of the minerals in the cleavage or in the rock. The cleavage planes

*need not* be either statistically or actually axial plane structures, although they invariably are if the cleavage is due to folding movements. Fracture cleavage has been induced in coarse sandstones adjacent to the Knowsley East Fault, near Heathcote (Fig. 5).

The cleavage is a prominent fabric element with the planes spaced at intervals of  $\frac{1}{2}$ " to 3 ft. It has a strong preferred orientation, making an angle of  $30^\circ$  to the fault. It is a shearing phenomenon resulting from stresses set up in the sandstones during the fault movement. The angular relationship between the cleavage planes and the fault defines the sense of slip on the fault. Wilson (1961) showed that the angle between fracture cleavage and the plane of movement reflects the nature of the rocks in which the cleavage occurs. In plastic beds, it is usually an acute angle but in brittle beds it may approach  $90^\circ$ . If this is so it must be inferred that the now brittle sandstones near Heathcote must have been in a plastic condition at the time of fault movement.

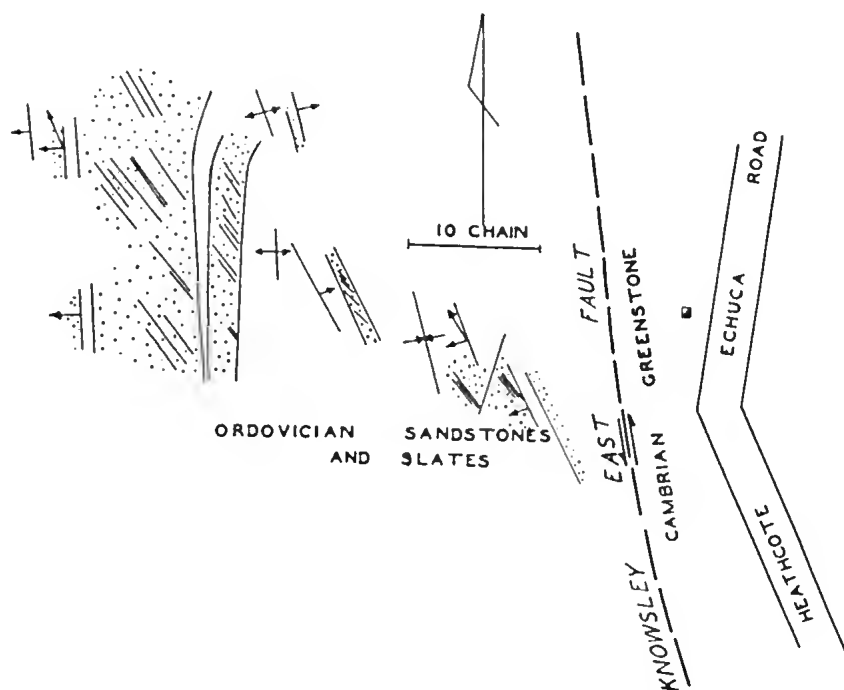


FIG. 5—Map showing fracture cleavage in sandstones, Knowsley East.

Similar fracture cleavage in sandstones has been noted at a few other localities in Western Victoria associated with major faults, e.g. on the Muckleford Fault near Maldon and on the Rowsley Fault near Anakie. Fracture cleavage due to slip on bedding planes during folding does not appear to have formed in the Victorian Ordovician sediments, although it is a prominent structure in the folded Silurian and Devonian sediments in central Victoria. Hills (1963) has described 'fissuring' in sandstones as a fracture cleavage, but this structure has more the features of

strain-slip cleavage than of fracture cleavage. The absence of fracture cleavage may be explained by either assuming it was formed in the earlier stages of deformation and was modified in the later stages to a strain-slip cleavage; or, alternatively, it may be that the tectonic environment of the sediments during folding was such that the fracture cleavage was unable to form.

Hills (1963) has recorded true fracture cleavage in an early-formed bedded quartz vein at Castlemaine, due to differential movements on the boundary surfaces. The brittle quartz would tend to fail in this way.

#### SLATY CLEAVAGE

Slaty cleavage, or flow cleavage, results from the recrystallization of pelitic sediments while they are undergoing internal deformation due to the application of external stresses: it is expressed as a parallel preferred orientation of the fine platy minerals which make up the rocks. Its deformation involves compression normal to the cleavage, and elongation in direction of easiest relief, as well as internal rotation. Elongation was noted by such early workers as Sorby (1843) and Sharpe (1847), and the evidence for this strain phenomenon has been summarized by Fourmarier (1947). In the Ordovician slates of Western Victoria, evidence of elongation is found in deformed graptolites. A detailed study of this deformation was made by Hills and Thomas (1944) who found a compression normal to the cleavage of up to 60 per cent and elongation parallel to the cleavage of up to 25 per cent. The extension of these rocks parallel to the *B* tectonic axis has had a profound effect on the style and symmetry of the mesoscopic folds.

Slaty cleavage is now generally accepted as being the result of laminar flow within the deforming pelites. Maxwell (1962) has suggested, however, that slaty cleavage formation is not necessarily a phase of a metamorphic sequence, and has shown that slaty cleavage may form in the initial stages of folding particularly if a thick sequence of high moisture-content, rapidly subsiding pelites is involved. This idea will be shown to be of considerable importance later in this paper.

Slaty cleavage is an axial plane structure: in the rocks under discussion it is commonly truly parallel to the axial surface of the fold in which it occurs, although sometimes because of curvature due to textural variations, it is only statistically parallel to the axial surface. Fanned slaty cleavage has not been observed on a mesoscopic scale, although this pattern has been recorded macroscopically in the Chewton-Maldon district (Beavis 1964b). In the region west of the Heathcote axis, slaty cleavage, with only local exceptions, dips very steeply to the east, or is vertical. In this region the cleavage is ubiquitous in the Ordovician pelites, but it is absent from the Cambrian rocks and from the Siluro-Devonian rocks of Central Victoria. This has a profound effect on the style of the mesoscopic folds: those of the Ordovician rocks have a near ideal similar style, whereas those of the Cambrian and Siluro-Devonian rocks show some quite pronounced departures from this style.

Where the Ordovician rocks have been recrystallized, there has been an emphasis of the slaty cleavage, which is expressed as a schistosity, but commonly, the dominant foliation in the schists is a layering due to bedding lamination. Axial plane foliation in the schists has usually maintained the simplicity of the original slaty cleavage. In local thermal metamorphism of slates about batholiths, recrystallization has tended to emphasize the slaty cleavage, so that, on a textural basis, the contact rocks 'may be described as schists, rather than hornfelses' (Beavis 1962b).

Slaty cleavage has not been imposed on the sandstones although a fine shear cleavage, geometrically and genetically related to the slaty cleavage, is present in

zones of intense deformation. The cleavage is due to flow (shear) in the fine matrix together with a dimensional preferred orientation of the characteristically sliver-like grains of quartz and feldspar in the plane of movement. The dimensional orientation of the quartz and feldspar results from rotation during cleavage development, or, in some cases, through dislocation of the grains by cleavages. No recrystallization of the quartz is apparent in these cases. This cleavage is most common in the hinge zones of mesoscopic folds where internal stresses would have been quite intense during deformation.

In the western area, the slaty cleavage is typically undeformed; any deformation of this structure is quite local adjacent to major faults (e.g. the Rowsley and Hanover Faults—see Beavis & Beavis, in prep.) and large batholiths such as near Harcourt and Ararat.

#### STRAIN-SLIP CLEAVAGE

In two earlier papers, the writer has discussed strain-slip cleavages in some of the Victorian Ordovician rocks. Strain-slip cleavage consists of laminar domains of intense shearing in which the minerals have undergone considerable reorientation (Knill 1960; Turner & Weiss 1963). It is the reorientation of the minerals, particularly, which distinguishes this form of cleavage from fracture cleavage.

In the coarser greywackes of the Ordovician rocks, strain-slip cleavage tends to be restricted to the hinge zones of mesoscopic folds; where the folding is tight and close, it may occur in the limbs also, in which case the domains are more widely spaced. In beds with uniform texture it is planar, but in graded beds, it is invariably curved. Hills & Thomas (1945) termed the strain-slip cleavage in sandstones 'fissuring' and since this term is generally accepted in Victorian geology, it is well to retain it. Fissuring was described by Hills and Thomas as 'zones varying in width up to about 1 inch, in which the rock is strongly sheared . . . they make a high angle with the bedding . . . and . . . are radially arranged in a fold'.

In the hinge zones of folds, a cusped structure is associated with the fissuring at the base of the sandstone beds (Plate 23, fig. 2).

The cusped structure, to be regarded as a rudimentary mullion, is obviously of tectonic origin, and its formation was assisted by the plastic condition of the sediments at the time of folding. It is restricted to hinge zones and the long axis is invariably parallel to the fold axis. The mullions occur in both anticlines and synclines, almost invariably on the lower surface of the bed.

Fine conjugate shears are frequently developed symmetrically about the fissuring. This was noted by Hills and Thomas in the Napoleon Anticline at Bendigo, and has since been observed in a number of other localities (Plate 23, fig. 1). The effect of this conjugate cleavage has been to produce a 'lozenge structure' (Plate 24, fig. 1) on the bedding planes. The long axis of the lozenge structure is parallel to the fold axis.

Small crenulations may be associated with the fissuring in sandstones, particularly in the finer textured sections of oscillatory graded beds (Plate 25, fig. 2). These crenulations lack the complexity of those found in the finer slaty siltstones. A typical example is shown on Fig. 6b.

The fine detail of fissuring can be seen in thin section. Domains not visible mesoscopically may be seen microscopically, indicating that even in quite coarse sandstones, fissuring may be microscopically penetrative. Examples from Bendigo have been figured by Hills (1963) but the most interesting examples recorded during the present survey were at Bristol Hill, Maryborough. Thick, coarse textured sandstones have a fine microscopic cleavage parallel to the mesoscopic fissuring.

A lamprophyre dyke, intrusive into the sandstone and post-dating folding, is also cleaved, the cleavage domains being continuous across the contact, with slight refraction.

The phase of folding, during which fissuring developed, and the nature of the internal stresses developed, are problems at present under investigation. The radial fanned arrangement of the cleavage defines it as *hOl* structure, immediately suggesting tensile fracture: however, the shear characteristics of the cleavage domains tend to preclude this interpretation; moreover, in graded beds, the fissuring passes up into normal strain slip cleavage in the finer textured rocks. The fissuring was formed at a stage when the sandstones and slates were sufficiently plastic for flow zones to develop in them, while the fanned pattern suggests that flexure and bedding plane slip were active mechanisms in the folding process. This, in part, accords with the views of Hills & Thomas that the fissures were essentially 'flow

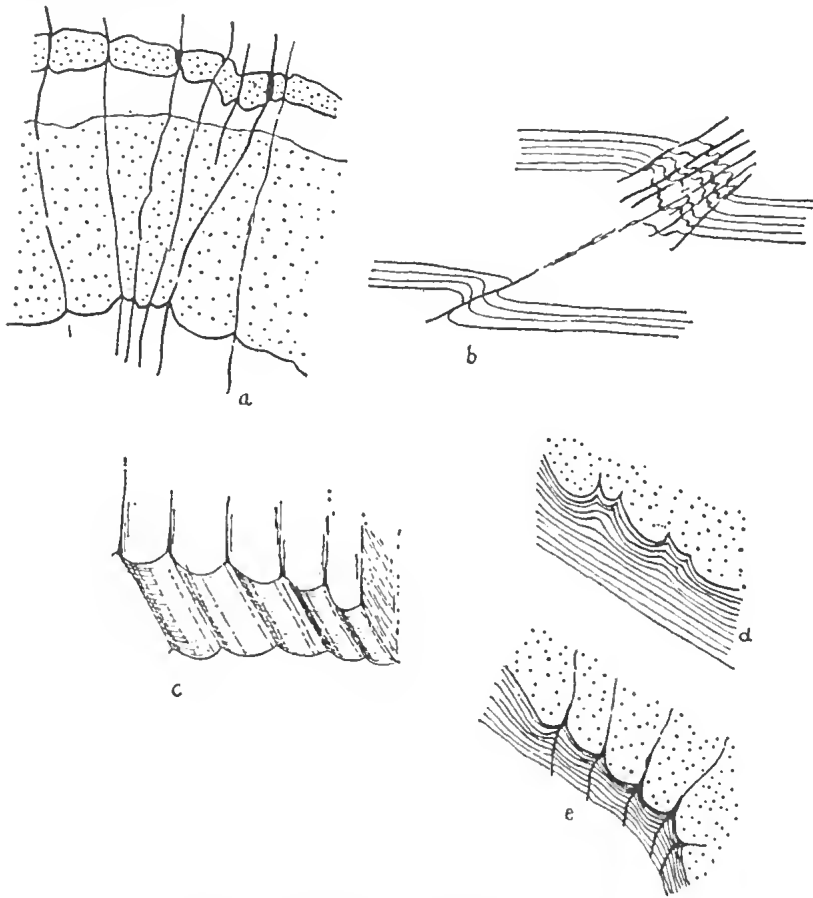


FIG. 6—Strain slip cleavage in sandstones.

- a. Fine cleavage domain in metagreywacke, Big Hill, Bendigo.  $\times \frac{1}{4}$ .
- b. Fine domain in greywacke, Break O'Day, Kangaroo Flat.  $\times \frac{1}{2}$ .
- c. Mullion structure on fissuring, Steiglitz.  $\times \frac{1}{20}$ .
- d, e. Fissuring in sandstone, Steiglitz.  $\times \frac{1}{20}$ .

layers in which plastic flow was particularly strong'. The problem is complicated, however, by the mounting body of evidence of two phases of strain-slip cleavage during folding: one synchronously with slaty cleavage while the rocks were plastic, the other at a late stage, when the rocks were brittle.

The sequence of events leading to fissuring can be seen clearly in a series of folds near the junction of Yankee Gully and Grahame's Gully, Steiglitz (Fig. 6d, e). Here in folds with varying degrees of tightness, rudimentary mullions are to be seen in open folds, *without* associated fissuring. In tighter folds, small fissures have formed in the sharp angles of the mullions; the acme of fissuring is to be seen in the tightly appressed folded sandstones. That nicks in the base of the sandstone acted as 'triggers' for fissuring, as suggested by Hills & Thomas, is supported by these observations.

In the finer textured pelitic sediments, the strain-slip cleavage may have one (or more) of the following styles: parallel, continuous first order shears; parallel sets of second order shears; conjugate sets of second order shears. Two generations of strain-slip cleavage have been recognized locally in the region west of the Heath-

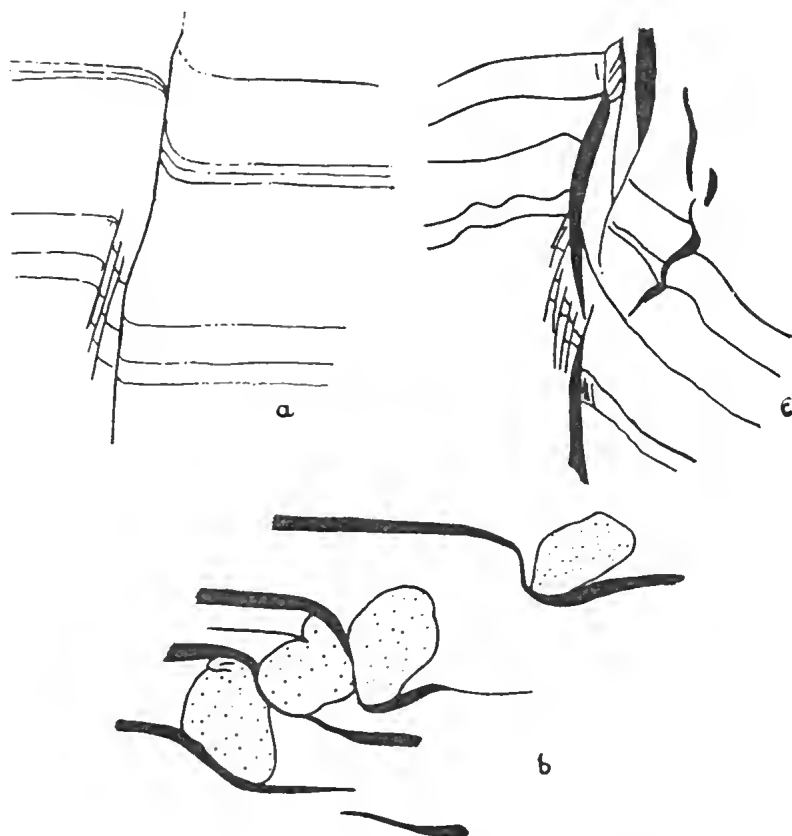


FIG. 7—Strain slip cleavage in pelitic sediments.

- a. Parallel, continuous first order cleavage, Castlemaine.  $\times 4$ .
- b. Second order cleavage, Morrions.  $\times 4$ .
- c. Conjugate second order cleavage, Sheoaks.  $\times 4$ .



cote Axis, while there is evidence of two phases of first-generation strain-slip cleavage. Some examples of the various styles are shown in Fig. 7.

The second order shears normally consist of lenticular domains lying *en echelon*. Each domain has a thickness of from 1 to 5 mm, the thicker being groups of fine shears, individual members of which are visible only microscopically. As pointed out in an earlier paper (Beavis 1964a) both first and second order cleavages show curvature across graded beds, and are refracted at bedding planes.

Small folds associated with the cleavage have a variety of styles. The main factors controlling the style of small folds are lithology and the style of the cleavage. In most cases folding resulted from both movement on the cleavage and flexure of adjacent, often unclesaved laminae.

Extreme movement in which thin beds of plastic sandstone have been involved may result in the disruption of the sandstone laminae to form ovoid fragments (Fig. 7b), the long axes of which lie in the fold axis. This structure is observed only rarely, and then only in intensely deformed zones. The finer sediments curve around the ovoids, the form of which emphasises the importance of rotation and elongation during the imposition of strain-slip cleavage.

In the metamorphic rocks of Western Victoria, strain-slip foliations may have been imposed before, during or after metamorphism. Irrespective of the time relationships of the cleavage and metamorphism the style of the cleavage has been conditioned by rock type.

In considering strain-slip cleavage it is essential to distinguish the relationship of the cleavage to the folding, since there have been shown to be, at least locally, two quite distinct generations of strain-slip cleavage in the Ordovician sediments. The first generation, genetically related to the folding of the rocks, occurs throughout the full distribution of Ordovician rocks west of the Heathcote Axis, but shows an environmental restriction. It is a planar structure statistically parallel to the axial planes of the folds. This strain-slip cleavage is found only in the hinge zones of the mesoseopic folds, and then only in the sandstones and siltstones. It is absent from the pure pelites. Thus, on the Moorabool R. near Meredith, fine textured, tightly folded slates exposed in a quarry lack strain-slip cleavage; downplunge, overlying oscillatory graded siltstones show intense deformation by strain-slip cleavage.

The second-generation strain-slip cleavage recorded in these rocks is very restricted in distribution: to date it has been noted only about the Harcourt Batholith; in the Anakie-Steiglitz area near the Hanover and Rowsley Faults; at Ingliston in the contact aureole of the Ingliston granodiorite, and west of Ararat. This cleavage, with the associated lineations, is the only evidence of multiple deformation of the Ordovician rocks west of the Heathcote Axis, and it is inferred that this group of rocks has, in general, suffered only a single folding.

Although the second-generation strain-slip cleavage has an areal restriction, where it does occur it is *not* controlled by structural environment or lithology as is the first generation. It is found in limbs and hinge zones of folds, and in all of the rock types. It is sharply discordant to the main structures and this geometric discordance reflects a lack of genetic relationship to the main structures.

As well as the two generations of cleavage, it is necessary to consider two phases of strain-slip cleavage in the folding of the rocks. There is some evidence that the strain-slip cleavage of the first generation developed synchronously with the folding of the still plastic sediments. However, in some cases, slates do show 'Gleitbretter' effects, which could be developed only if the slate were in a brittle condition, i.e. in the later phases of the folding. This effect, noted particularly in the Castlemaine district, may argue a continuous cleavage development, or it may

argue this type of strain slip cleavage formation due to renewal of stresses in the late stages of the folding deformation.

### LINEAR STRUCTURES

Linear structures are penetrative on the mesoseopic scale; they include lineations *sensu stricto*. The linear structures may be parallel to the direction of movement *a* but, in the rocks under discussion, with one exception, all of the linear structures recorded were parallel to the axes of the folds in which they occurred. Linear structures recorded were: lineations in the bedding (*S*<sub>0</sub>) due to the intersection of planes of movement (slaty cleavage *S*<sub>1</sub>, strain-slip cleavages *S*<sub>1</sub><sup>1</sup>, *S*<sub>2</sub>); lineations in *S*<sub>1</sub> and *S*<sub>1</sub><sup>1</sup> due to the intersection of these by bedding; lineations in *S*<sub>0</sub>, *S*<sub>1</sub>, and *S*<sub>1</sub><sup>1</sup>, due to intersection of these by *S*<sub>2</sub> (only in the areas of superposed *S*<sub>2</sub>); small crenulations in *S*<sub>0</sub> (and locally in *S*<sub>1</sub> due to superposed *S*<sub>2</sub>); lozenge structure; linear preferred orientation of mineral grains in *S*<sub>0</sub> and *S*<sub>1</sub>; stretched, detached and rotated ovoid fragments; mullions, boudinage and rodding.

In the rocks under discussion, there is, except for the areas mentioned above in which a second generation strain-slip cleavage has been imposed, a single lineation (although several styles may occur in the one exposure). This lineation is, with one exception, parallel to the fold axis, i.e. it is a *B* lineation. The only *a* lineation recorded was in shale *S*. of Metcalfe. This lineation is a fine striation in *S*<sub>0</sub>, and may be the result of slip on bedding planes. Lineations in *S*<sub>0</sub> due to the intersection of this surface by *S*<sub>1</sub> are very fine microcrenulations, which sometimes have a similarity to very fine ripple marks (Pl. 25, fig. 1). In the coarser pelites this style has a gross form which could be mistaken for a primary structure (Pl. 25, fig. 2) until its intimate relationship to cleavage (*S*<sub>1</sub><sup>1</sup>) and its invariable parallelism to fold axes is established. Lineation in *S*<sub>1</sub> is a colour banding produced by textural and colour variations in the rock. These bands vary in width up to 1", and are irregularly spaced.

Very locally, for example near Ballan, fine penetrative conjugate cleavages in pelitic sediments have resulted in a penetrative 'penril' structure, which is a *B* linear structure. This structure is sometimes reminiscent of flow structure and suggests flow parallel to *B* in a deforming plastic sediment.

Lozenge structure, closely related genetically to the coarse ripple lineation, is due to the intersection of the bedding of coarser greywackes by conjugate strain-slip cleavage (Pl. 24). The boundaries of the lozenges, as well as the long axes, are statistically parallel to *B*. This linear structure is restricted to the base of coarse beds and laminae in the hinge zones of mesoseopic folds.

Small folds, commonly called congruous drag folds, occur frequently in the limbs of mesoseopic folds, but they are not as common as is often believed. They vary in dimensions, and are invariably parallel to the axis of the larger fold in which they occur. Normally, these folds are developed in sandstones, but slates may also be involved. The form and style of the small folds may not accord with that of their hosts. With decreasing size they merge into microcrenulations. Normally ascribed to drag on bedding planes during flexure of the deforming rock mass, some, at least, are due to movement (slip) on cleavage.

Stretched, rolled and detached fragments forming linear structures have been described earlier in this paper (see page 159). The ovoids lie in a line parallel to the fold axis, and their long axes themselves are parallel to this axis. This form of structure implies intense deformation of plastic beds with elongation in, and rotation about, *B*.

The parallel orientation of elongate mineral grains is a characteristic lineation

in the crystalline schists of far Western Victoria: amphiboles, micas and ellipsoidal porphyroblasts of cordierite may be involved. Less common is the orientation  $S_1$ , of 'spots' of incipient andalusite in hornfelses at igneous contacts. This type is particularly well developed in the Wedderburn-Kingower district.

Throughout the world, mullions seem to have been developed best in high-grade metamorphic rocks, although Pilger and Schmidt (1957a, b) recorded them from relatively low-grade rocks in North Eifel. Rudimentary cleavage mullions have been described earlier. Both fold and cleavage mullions have been recorded from Casterton by Wells (1956). Rodding has not been either observed or recorded in the Ordovician rocks W. of the Heathcote Axis.

Boudinage is a rare linear structure: recorded from medium grade schists at Casterton by Wells, this is the only known occurrence in Western Victoria. A rudimentary type has been observed near Meredith and Ballan.

It is noteworthy that rectilineations are rare in the Ordovician rocks. Even on the scale of the handspecimen the lineations are frequently curved. On a larger scale, the curvilineations reflect the reversal of plunge of axes of folds, but on a smaller scale, curvature is due to slight variations in attitude of cleavages resulting from lithological changes.

Throughout the western area of Ordovician rocks, there is a single lineation. Multiple lineations, associated with superposed cleavages, and geometrically and genetically unrelated to the folds, have been noted only about the Harcourt Batholith, in the Inglis-Anakie-Steiglitz area and the Ararat district. In these cases, there are at least three lineations due to intersections of  $S_0$  and  $S_1$ ;  $S_0$  and  $S_2$ ; and  $S_1$  and  $S_2$ .

#### FOLD STRUCTURES

Folds are the most prominent mesoscopic elements in the structure of the Ordovician rocks. The folds range from minute, barely visible structures, to very large anticlinoria and synclinoria, the existence and form of which can be determined only after detailed stratigraphic and structural mapping. Throughout, the style and geometry of the mesoscopic folds are relatively constant. Local variations are apparently due to lithology: thus the form and geometry of a fold in thin interbedded slates and sandstones will differ from those of a fold in thick slate, thick sandstones, or oscillatory graded greywackes. The style of the mesoscopic fold is everywhere close to 'similar' even where thick, supposedly competent sandstones are involved.

Most of the mesoscopic folds are asymmetric, and slightly overturned. The westerly limb has steeper dip than the easterly; overturning is to the W., with the axial planes dipping steeply E. Superficially the folds have monoclinic symmetry, but consideration of all the elements of a fold shows that the symmetry is usually triclinic. In the geometric terms of Turner & Weiss (1963), the folds can be described as inclined, non-plane, non-cylindrical. The hinge lines are curvilinear and the axial surfaces frequently curved.

One of the most striking features of the mesoscopic folds is the change of plunge, both in the direction and degree within quite short distances: frequently less than 100 ft. An example of this is shown on Pl. 26, fig. 1, from near Woodend. The plate illustrates a cutting on the Calder Highway, almost coincident with the axial surface of a fold. Variation in plunge from a few degrees to over  $30^\circ$  can be seen. Viewed in its broadest sense, this geometry is a typical  $B \perp B'$  type, and is characteristic of the folds on all scales. There is a second effect, noted by D. E. Thomas at Chewton, but typical of the Ordovician rocks generally: the transition

along the hinge lines of anticlines to synclines and *vice versa* so that an *en echelon* pattern of folds results. This, too, occurs at all scales.

The whole fold system clearly has been influenced by the resistance to elongation in *B*, although some elongation has occurred. This resistance has resulted in buckling on  $B^1$  axes more or less normal to *B*: it would also accentuate flow in *a*. Release of residual stresses in *B* after the cessation of folding would result in the opening of *ac* tension joints: joints which are extremely prominent in these rocks.

As previously noted, the form and style of the mesoscopic folds vary with lithology, but there appears to be little significant variation with stratigraphic position. Any apparent variation with stratigraphic position is a lithological effect—e.g. pre-Darriwilian sediments contain a relatively high proportion of sandstones, while this proportion decreases sharply in the Darriwilian and post-Darriwilian rocks. The folds in slate are sharp with rounded hinges, but they may occasionally be quite angular, or even flat. Flat open folding is more characteristic of the sandstones. Ramsay (1962) discussed the geometry of folds and the mechanism of folding, and showed that, for 'similar' style folds, flattening was important in the deformation. Fig. 8 illustrates the geometry of a typical fold. It will be noted that thinning of the limbs occurs even in the sandstones. This is less severe than in the slates, but it is a persistent feature in the sandstones throughout the sequence.

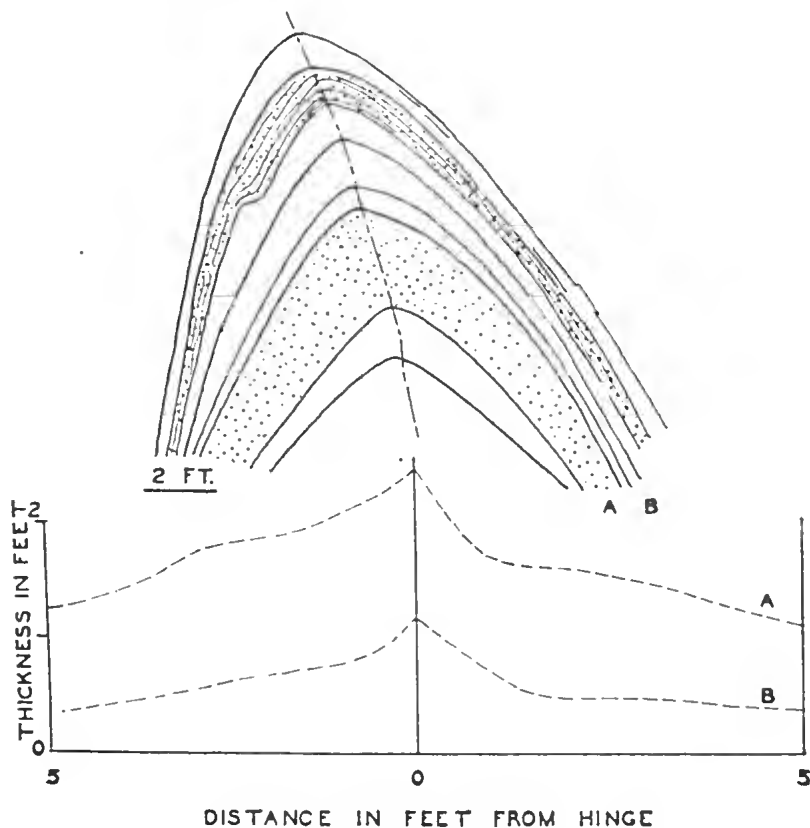


FIG. 8—Geometry of a fold in interbedded slates and sandstones, Castlemaine.

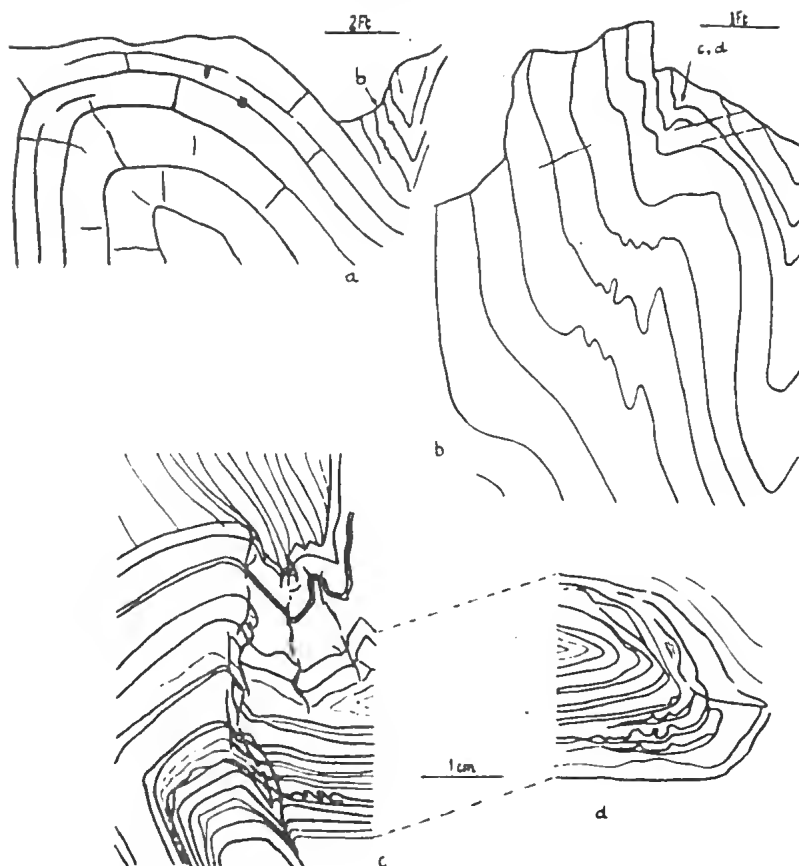


FIG. 9—Anticline in fine textured greywacke, Moorabool R., Meredith.  
 a. Large scale mesoscopic anticline.  
 b. Small scale folds on E. limb of (a).  
 c-d. Microscopic fold in one limb of (b).

Small-scale folds on the limbs of the larger mesoscopic folds rarely have the same style and geometry as the large folds. This is illustrated for folds at three scales on Fig. 9.

It is likely that the smaller the scale the more important become the internal stresses as factors controlling the form of the fold. Minor textural and lithological variations similarly would assume greater significance. Since small-scale folds tend to be more developed in the hinge zone of mesoscopic folds, it might be enquired whether mesoscopic folds are more frequent, or more complex in the hinge zones of the macroscopic folds. At present there is no evidence to suggest that this is so.

#### MACROSCOPIC STRUCTURES

##### FOLDS

Macroscopic folding is known in detail only in the belt of sediments bounded on the west by a N.-S. line through Dunolly and Maryborough, and on the east by the Heathcote Axis, i.e. the belt of graptolite-bearing sediments. Even within this

belt, absence of fossiliferous beds and the cover of younger rocks has often resulted in an inability to determine detail. The most westerly of the fossiliferous beds are Lancelian; W. from the Muckleford Fault, the highest beds known to occur are Chewtonian, with *Didymograptus protobifidus* along the hinge of the Werona Synclinalium. The Muckleford Fault, then, would appear to mark an important boundary in the fossiliferous rocks of the Western Trough.

In the extreme W., the only structural mapping which has defined macroscopic folds is that of Clappison (1960) at Stawell. Here, an anticlinorium and a synclinalium have been mapped; both structures have tightly folded western limbs, while the eastern limbs have been sheared out. Plunge is gentle, but dome and basin structure is apparent.

In the Ballarat district, the mapping of Baragwanath (1917) has suggested the development of anticlinoria and synclinalia, but the most westerly of such macrofolds, for which there is indisputable evidence, is the Werona Synclinalium, succeeded to the east by the Maldon Anticlinorium. To the south is the imperfectly known Elaine Anticlinorium; the eastern boundary of these two anticlinoria is formed by the Muckleford Fault.

Easterly from the Muckleford Fault, all of the graptolite zones are represented, from basal Lancelian through to Bolindian. The Upper Ordovician zones are restricted to a narrow belt in the Riddell Synclinalium, immediately W. of the Heathcote Axis. Between the Muckleford Fault and the Heathcote Axis, the Riddell Synclinalium is by far the largest macrofold and tends to dominate the structure. In the N. Castlemanian beds are exposed: due to southerly plunge, these are succeeded to the S. by Yapeenian, Darriwilian and Upper Ordovician beds. This occurrence of Upper Ordovician W. of the Heathcote Axis is unique, and it is significant that these beds are restricted to the eastern-most sector.

The axes of the known macrofolds have a trend usually a few degrees W. of N.; all, however, show a slight curvature concave westerly, a feature also of the Heathcote and Dookie-Tatong Axes. Except locally, the axial surfaces of the mesoscopic folds have a steep easterly dip, and the folds are slightly overturned to the W. It is reasonable to assume that the macrofolds, similarly, show this westerly overturning. In the region occupied by the Expedition Pass Synclinalium, the Trentham Anticlinorium and the Muckleford Synclinalium, the axial surfaces are fanned (Beavis 1964b), a feature related to past folding deformation by the Harecourt Batholith.

In order more fully to investigate the geometry of the macrofolds, a part of the Axedale Anticlinorium was studied. The area selected, lying to the SW. of the township of Axedale, had previously been mapped in part by J. J. Caldwell (1931). New collections of graptolites were made from Caldwell's localities, and new fossil localities were discovered and zoned. More structural data (bedding, cleavage, lineations, fold hinges) than shown by Caldwell were also assembled. The data and the interpretation of these data are shown on Fig. 10.

It must be noted that, because of the scarcity of fossils, detailed zoning was not possible in the Lancelian and that it was necessary, in some instances, to map as one unit, two or more zones (e.g. Be 1 and Be 2).

Statistically, the fold axes have a plunge  $15^{\circ}$  NNW. Local reversal of plunge occurs but southerly plunge is rare. Dips of the beds are steep and the axial surfaces of the mesoscopic folds have steep easterly dip. Slates predominate, but the Lancelian belt is marked by abundant thick beds of relatively coarse sandstones and there appears to be a macro-gradation through the sequence.

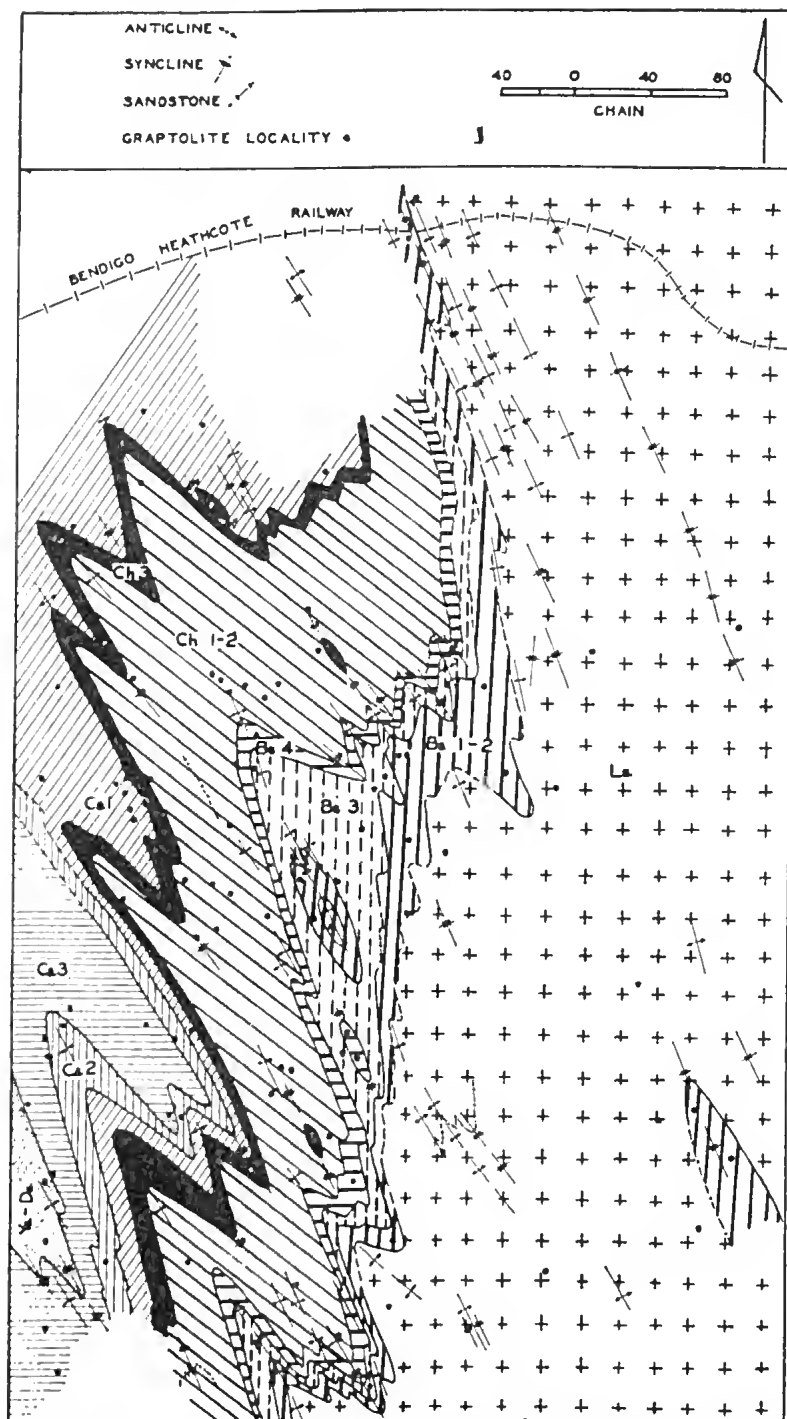


FIG. 10—Map of part of the Axedale Anticlinorium compiled from the writer's data and J. J. Caldwell's published map.

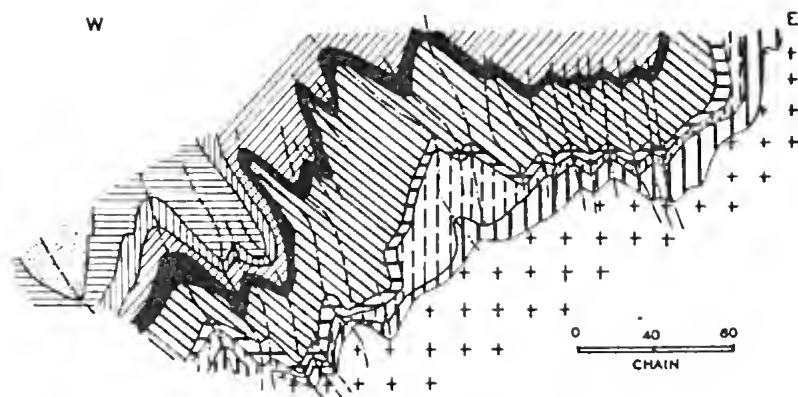


FIG. 11—Tectonic profile of part of the Axedale Anticlinorium.

On the macroscale, the map suggests similar style folding, with marked thickening in the hinge zones, particularly in the hinge zone of the anticline in the west-central sector, and thinning of the limbs. To illustrate the macrofold geometry, a tectonic profile (Fig. 11) was prepared. The profile is based on the assumption of a constant plunge of  $15^{\circ}$  WNW.

The tectonic profile, normal to the axis of the macrofold, demonstrates the precise geometry of the fold. The comparative simplicity of the folding in the Lancefieldian and lower Bendigonian beds, predominantly sandstones, can be con-

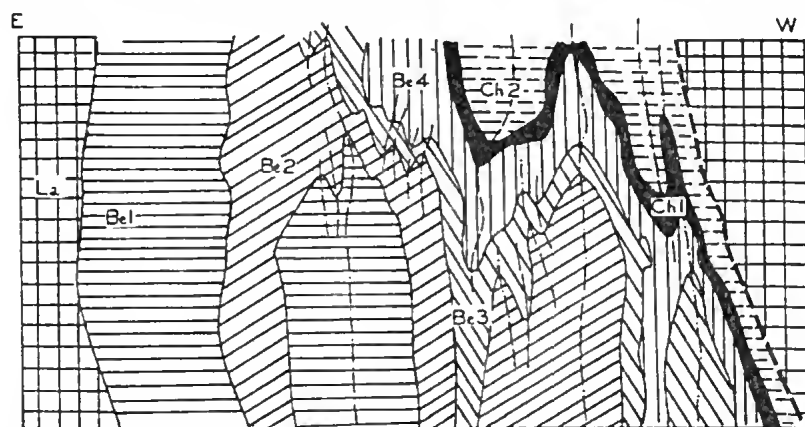


FIG. 12—Tectonic profile of part of the Werona Synclinorium, based on map by Harris and Thomas, 1948.

trasted with the more tortuous structure higher in the sequence. There is also a suggestion of increasing complexity low in the sequence as the centre of the syncline in the west is approached. Perhaps the most important feature of the profile, however, is the evidence of movement towards the W., with curved and inclined axial surfaces. It is clear too that the style of the macroscopic folding, in the structure at least, shows some significant departures from the almost ideal similar style of the mesoscopic folds.

A profile was also prepared for part of the Werona Synclinorium (Fig. 12)



from the published map of Harris & Thomas (1948), where the regional plunge is southerly. Again, field checks were made and additional structural data collected.

This profile shows a number of features comparable with those noted for the Axedale structure. There is increasing tightness of folding higher in the sequence and towards the hinge zone of the macrofold; impersistence of individual folds as departures from the ideal similar style are also to be noted. There is a suggestion in this profile of irregular zonal boundaries low in the sequence, which *may* imply contemporaneous erosion. In some other areas there is evidence of poor development of some zones and it might be questioned whether there might not be locally throughout the sequence, small disconformities.

Study of the profiles and of published detailed maps shows that while folding tends to increase in complexity in the hinge zone of the synclinoria, it appears to be relatively simple in the hinge zones of anticlinoria. This is most certainly due to lithology. The Lancefieldian-Bendigonian beds have a very high proportion of sandstones. Higher in the sequence, the proportion of sandstones decreases, and slates and shales become more important.

The other possibility must not be excluded, viz. that, because of the scarcity of fossils in the Lancefieldian, zonal mapping without the detail possible higher in the sequence results in *appearance* only, of simplicity and in fact the folding might be uniformly complex throughout. With the evidence at present available, however, the former hypothesis is the more attractive.

#### FAULTS

Major faults are known with certainty only in the belt of fossiliferous rocks, or where younger, renewed movement has left a pronounced escarpment. As noted by Harris & Thomas (1948), the stratigraphic relationship on the faults is one in which the lower parts of the sequence (Lancefieldian and Bendigonian) occur on the W. of the fault, and abut against rocks high in the sequence, which occur on the E. side. Many of the more important faults have a meridional, or near meridional trend, e.g. Muckleford, Campbelltown, Rowsley, Djerriwarrh and Whitelaw Faults, but a few, such as the Hanover Fault, cut obliquely across the strike of the sediments.

All have been regarded as high-angle thrusts, movement on which post-dated the folding of the Ordovician rocks. On many of the faults, e.g. Whitelaw and Muckleford, renewal of movement took place in the Tertiary. Late movement on these faults is often reflected in well developed escarpments, although some of the escarpments may be rather the result of differential erosion, e.g. the massive sandstones on the W. side of the Whitelaw Fault abut against soft shales on the E.

The relationships along the Muckleford Fault mark this structure as one of special significance. With the exception of a small occurrence of Chewtonian on the hinge of the Werona Synclinorium, only Lancefieldian and Bendigonian beds occur W. of the fault. This raises the question of whether any significant post-Bendigonian deposition took place W. of the fault. It is suggested here that the Muckleford Fault was an active structure during deposition and folding of the sediments, and that the Western Trough, W. of the Muckleford Fault, ceased to exist in the Chewtonian. Thereafter, deposition was restricted to a narrow trough confined between the Muckleford Fault and the Heathcote Axis. This implies also that the Muckleford Fault was a normal fault downthrow to the E. rather than a thrust, with upthrow to the E.

First recognized in East Talbot (Harris & Thomas 1933) the Muckleford Fault has been traced from W. of Bendigo where the Ordovician rocks disappear beneath

the alluvium of the Northern Plains, S. to Maude, where the Ordovician rocks are covered by Tertiary marine sediments. (In this latter area, it was named the Meredith Fault by Harris & Thomas 1949. They suggested that the Meredith Fault might be a southerly continuation of the Muckleford Fault—a suggestion verified by work at present in progress in the Steiglitz-Meredith area.)

Detailed work near Guildford (Thomas 1934) showed that the total movement on the Muckleford Fault was of the order of 4,000 ft, with displacement of Tertiary gravels by 100 ft, and of Newer Basalt by 50 ft. It has been shown by the present writer (Beavis 1964b) that the Muckleford Fault transects the Harcourt Batholith with crushing of the granodiorite.

We may picture as the tectonic effect of the Muckleford Fault, deposition of Castlemanian through to Upper Ordovician confined to a long narrow deforming trough bounded by the Muckleford Fault and the Heathcote Axis, the Muckleford Fault being regarded as a fault unconformity. Deformation within this trough was such that, by the end of the Darriwilian, the major folds were fully developed and the Upper Ordovician sedimentation was confined to a shallow basin in the Riddell Synclinorium.

The western boundary of the Upper Ordovician sediments S. of Gisborne may be faulted, the boundary structure being the Djerriwarrh Fault (Harris & Crawford 1921). Re-examination of the area, using Harris's field map, has shown that, on the W. side of the fault, Chewtonian, Castlemanian, Yapeenian and Darriwilian graptolites occur, while to the E., Gisbornian graptolites are abundant. The displacement on the fault is therefore not great, and again it is possible that the structure is a fault-unconformity.

The displacement on the Hanover Fault, first mapped by W. H. Ferguson (1940), also appears to be small and it is possible that the strike-slip component of movement was important (Beavis & Beavis, in prep.). Chewtonian beds north of the fault, abut against Darriwilian, but work in progress shows over a considerable length Yapeenian and Darriwilian abutting against Darriwilian.

The remaining major fault known is the Whitelaw Fault, first recorded by W. J. Harris (1933). Here Laneefieldian and Bendigonian sandstones and thin slates abut against Darriwilian shales and slates. While displacement is considerable and exceeds that on the Muckleford Fault (5,000 ft) the tectonic significance of this structure does not appear to match that of the Muckleford Fault.

### **Ordovician Rocks East of the Dookie-Tatong Axis**

With the exception of small very restricted areas in the Mornington Peninsula and small faulted inliers in Gippsland, all Ordovician rocks in eastern Victoria occur to the E. of the Dookie-Tatong Axis. With few exceptions, these rocks are unfossiliferous, but where fossils occur, they are Upper Darriwilian, or, more frequently, Upper Ordovician forms. It is generally accepted on this evidence that the Ordovician rocks of the Eastern Trough are of Upper Ordovician age. In contrast to the rocks of the Western Trough, even the so called 'sediments' show a somewhat higher grade of regional metamorphism, while the centre of the area is occupied by a belt of schists and gneisses known as the Metamorphic Complex of north-east Victoria.

Published studies of the structure of the Eastern Trough have been infrequent, and hence little is known of the structure generally, which in any case is much more complex than that of the Lower Ordovician rocks in Western Victoria. Virtually all the geological studies have been concentrated in and about the Metamorphic Complex.

## MICROSCOPIC STRUCTURES

Petrofabric analyses of the rocks have been restricted to a few schists and gneisses of the Bogong High Plains area (Beavis 1962a) and of the Beechworth area (Beavis 1963; Leggo 1965). The quartz and mica subfabrics have, in general, a monoclinic fabric, although the quartz subfabrics of the coarser greywackes may be triclinic.

Almost invariably the biotite subfabric of the crystalline schists is represented by a single maximum defining the single foliation, although in some of the low-grade schists, the maximum to the (001) biotite shows considerable spread due to two acutely intersection foliations; [0001] quartz generally lies in a girdle coincident with the foliation. In the crystalline high-grade schists there is usually a single girdle, but in the low-grade schists as many as three girdles have been found, corresponding to three foliations in the schist.

For various reasons discussed later in the paper, microscopic examination of the rocks in this region is often essential to ascertain the precise nature of a structural element under observation. Such examination may reveal other structural elements. Spindle structure (Beavis 1964c) is a typical example. This structure was first recorded in multi-deformed hornfels from Beechworth, but has subsequently been found elsewhere in NE. Victoria, e.g. at Mitta Mitta. These small quartz spindles parallel the axes of folds in which they occur, and for this reason they are of considerable value in geometric analysis. Like the more gross rodding described by Wilson (1953) they owe their origin to segregation of quartz from the fine laminae in which they occur.

## MESOSCOPIC STRUCTURES

## BEDDING AND LITHOLOGICAL LAYERING

Bedding is difficult to detect in thick slates and pelitic schists, but the greywackes and their metamorphic equivalents have a clear internal bedding lamination. Graded bedding is characteristic of the coarser textured rocks, and may be simple or oscillatory. In some cases, segregation of quartz has occurred in the hinges of small folds, which imparts, in the field, the appearance of a second lamination. Fine current bedding and fine ripple marks have been recorded in the sediments, but have not yet been recognized in the crystalline rocks.

In an earlier work (Beavis 1962a) it was stated that for the Bogong High Plains area, 'in the slate, bedding is the only *s* surface uniformly developed' and that cleavage in the slates is usually, but not invariably parallel to the bedding. It was also stated that the foliation of the schists in this region was parallel to the bedding in the parent sediments. More recent study has shown that the first of these statements is erroneous: in fact, slaty cleavage  $S_1$ , is usually the dominant planar surface in the slates, and constitutes the form surface of many mesoscopic folds. However, examination in thin section under the microscope may be essential to determine the nature of the mesoscopic *s*. This is illustrated by Pl. 27, fig. 2. The second statement, that cleavage and bedding are parallel, is also erroneous, at least in part. Throughout the Eastern belt of Ordovician rocks, the slaty cleavage cuts acutely across, or is parallel to, the bedding, on the limbs of folds. In the hinge zones of folds, the cleavage may intersect the bedding at right angles. Since, as will be shown, superposed folding has occurred on a regional scale in eastern Victoria, the bedding-cleavage relationships depend on the nature and generation of the cleavage and also on the nature of the form surface of the folds.

The nature of the foliation in the schists is uncertain. Since the earlier work cited, further evidence has been obtained to show that in some of the low-grade schists at least, the lamination is not primary but is a result of metamorphic segregation into lenticular quartz-albite laminae alternating with continuous quartz-chlorite-biotite laminae, often transected by strain-slip (crenulation) cleavage. It is quite clear, however, that the high-grade schists and gneisses possess a single foliation, in contrast to the two imposed foliations in the lower-grade rocks on the margins of the Metamorphic Complex.

#### CLEAVAGES AND FOLDING

In the more westerly exposure of the Ordovician rocks, as for example in the Mt. Wellington area, there is a slaty cleavage and, in the hinge zones of folds, in the more arenaceous sediments, an axial plane strain-slip cleavage more or less synchronous with the slaty cleavage. There is, however, a second-generation strain-slip cleavage (crenulation cleavage) sporadically developed. As one goes further E., the crenulation cleavage becomes more pronounced and often becomes almost a penetrative foliation. In the Ordovician rocks of eastern Victoria there is evidence of three generations of folding, of which two have taken place on a regional scale, and one only locally.

##### (i) *First Generation Mesoscopic Structures:*

Folds of the first ( $F_1$ ) generation include macroscopic structures, the form and geometry of which can only be surmised, as well as mesoscopic folds with hinges at intervals of from 10 to 250 ft (Fig. 13). The mesoscopic  $F_1$  folds may be open

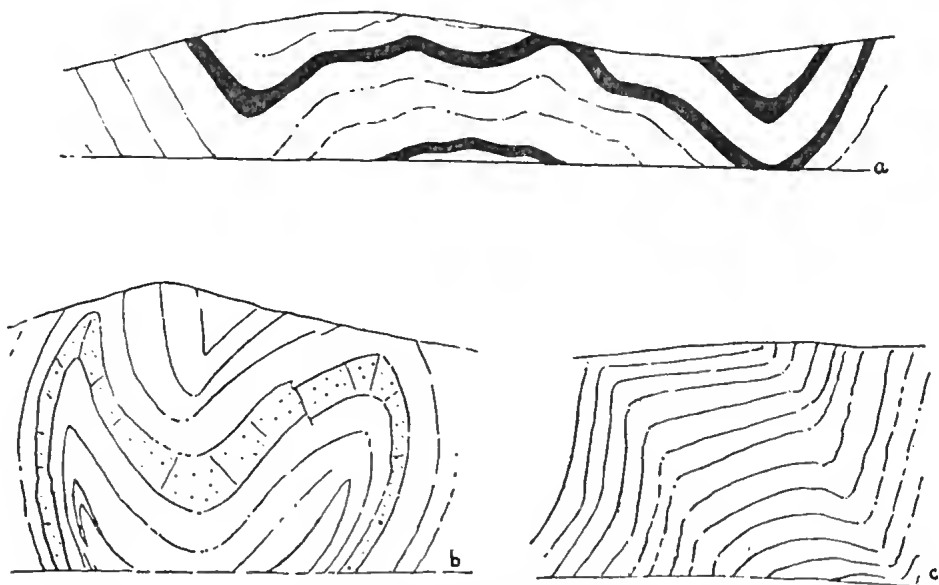


FIG. 13—First generation folds.

- a. Road section near Sambas Mine, Harrietville. Length of section 55 ft.
- b. Road Section on the Omeo Highway,  $1\frac{1}{2}$  miles S. of Mitta Mitta. Length of section 32 ft.
- c. Road section on Omeo Highway, 5 miles S. of Mitta Mitta. Length of section 8 ft.

(Fig. 13a) or they may be tightly appressed (Pl. 27, fig. 1). They are asymmetric, slightly overturned with usually a westerly vergence, although there are well defined belts in which the vergence is easterly. The axial surfaces are curved (Fig. 13b) and the hinge lines curvilinear. The non-plane non-cylindrical geometry of the  $F_1$  mesoscopic folds is due almost entirely to superposed folding.

The folds have aspects of both the similar and parallel styles, with the former predominating, particularly in thick pelitic sequences. The gross configuration of the folds is highly variable. Both flexural slip and flow operated as mechanisms of the  $F_1$  folding, but flow seems to have been the more important.

In the hinge zones of the mesoscopic  $F_1$  folds, smaller folds, with maximum size of 6", have been formed due to intense internal stresses in these zones. These  $F_1^1$  folds are associated with movement on strain-slip cleavage,  $S_1^1$ . They occur in the coarser pelites and the finer arenites, but have not been observed in slates, phyllites, or the coarser sandstones. A wide variety of styles has been noted: hinges are frequently sharp, but never angular (Fig. 14), while the limbs are frequently dislocated by  $S_1^1$ . The geometry of the  $F_1^1$  folds accords precisely with that of the larger  $F_1$  folds in which they occur, and the two groups of structures are clearly of the same generation.

Small conjugate folds are relatively common  $F_1^1$  styles. These are of two types: one is due to fanned strain-slip cleavage (Fig. 14b), the other to conjugate strain-

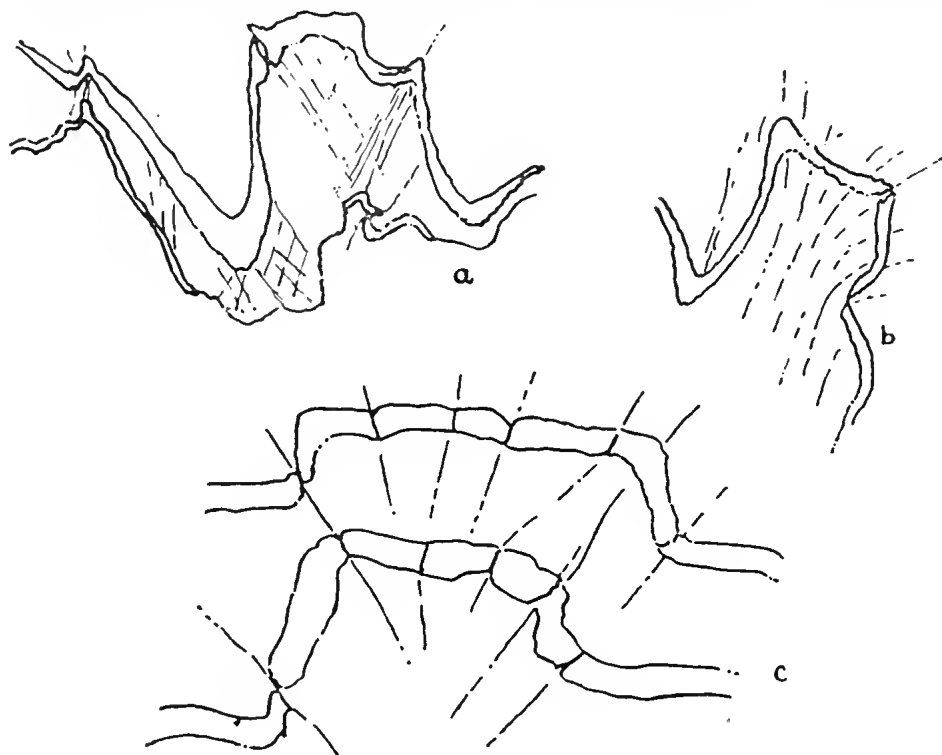


FIG. 14— $F_1^1$  Fold Styles.

- a. Similar style fold from  $F_1$  anticline, Bon Accord Spur, Hotham.  $\times \frac{1}{2}$ .
- b. Conjugate fold from  $F_1$  syncline, Harrietville.  $\times 1$ .
- c. Conjugate fold from  $F_1$  anticline, Mt. St. Bernard.  $\times \frac{1}{2}$ .

slip cleavage (Fig. 14c). Small *microcoulisse* and geniculate folds have been noted, but similar style small folds are by far the commonest. The axial surfaces of the  $F_1^1$  folds are curved and are parallel to  $S_1^1$ . The cleavage domains themselves may be arrays of second-order shear but they are usually continuous first-order shears, 0.5 mm thick, and spaced at intervals of from 1.5 to 3.0 mm. In places, the prolongation of the deforming stresses has resulted in  $S_1^1$  becoming a microscopically penetrative foliation.

Lination,  $L_1$ , parallel to the axes of  $F_1$  folds tends to be restricted to the pelitic rocks. Two styles are common; lithological banding in  $S_1$ , and micro-

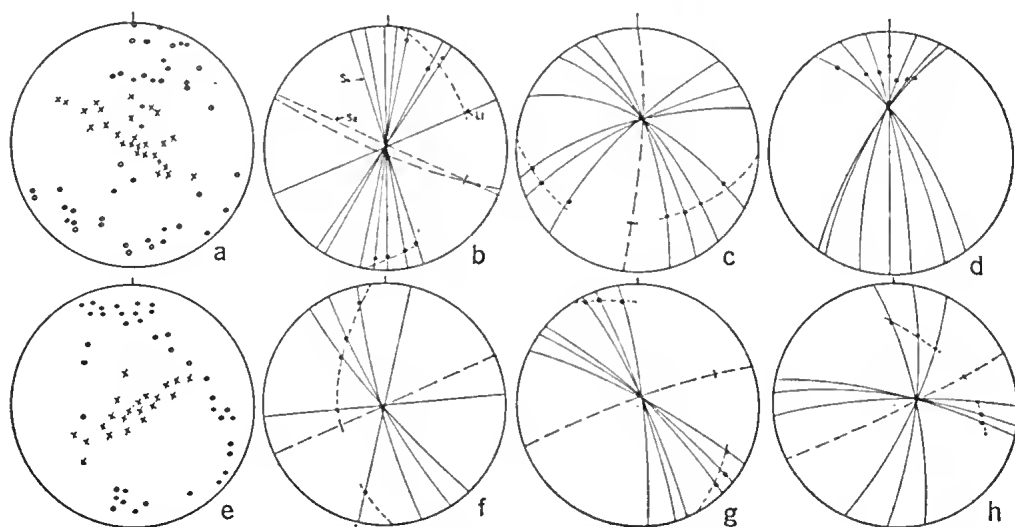


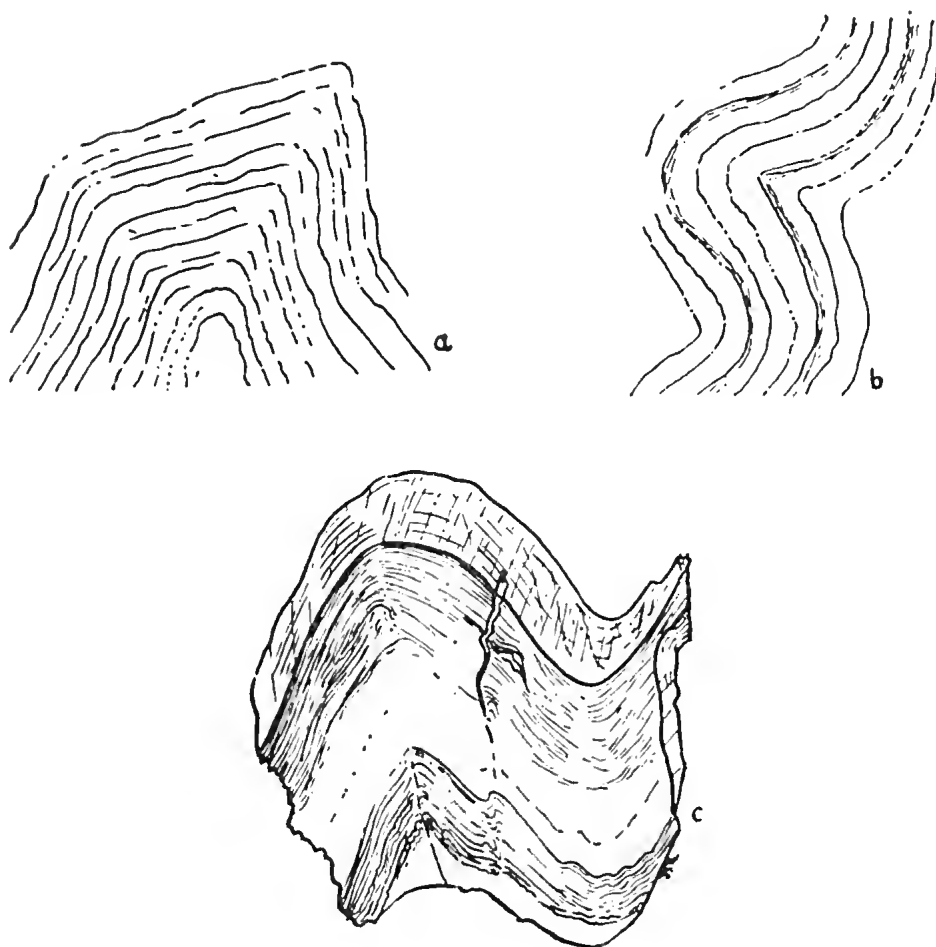
FIG. 15—Geometry of  $F_1$  and  $F_2$  Folds.

- a. Lineations in the Mitta Mitta Area.  $L_1$  o;  $L_2$  x.
- b. Geometry of  $F_2$  Fold, Magorra Gap, Mitta Mitta.
- c. Geometry of  $F_2$  Fold, Snowy Ck. West.
- d. Geometry of  $F_2$  Fold, Granite Flat.
- e. Lineations in the Upper Ovens Area.  $L_1$  o;  $L_2$  x.
- f. Geometry of  $F_2$  Fold, Harrietville.
- g. Geometry of  $F_2$  Fold, Mt. St. Bernard.
- h. Geometry of  $F_2$  Fold, Mt. Feathertop.

crenulations of  $S_0$ . This latter style is found also as a second generation lination, so that it is not a unique  $F_1$  structure. Where it is an  $F_2$  structure, however, it lies in both  $S_0$  and  $S_1$ , so that distinction is usually possible. Lithological banding, a deformed example of which is shown on Pl. 30, has a width ranging from 1 mm to 1 cm. The microcrenulations have a wavelength of 1 mm or less. Lination  $L_1^1$ , parallel to the axes of both  $F_1$  and  $F_1^1$  folds, consists of broadly spaced crenulations in  $S_0$  due to the intersection of this surface by  $S_1^1$ . Mullions, typically  $F_2$  structures, were recorded as  $L_1^1$  at only one locality, on the Alpine Highway, 1 mile S. of Harrietville.  $L_1$  and  $L_1^1$ , and hence the axes of  $F_1$  and  $F_1^1$  folds generally plunge gently, plunges in excess of  $30^\circ$  being rare. This is shown on Fig. 15 for the Mitta Mitta and Ovens Valley areas. Fig. 15 also illustrates the geometry of  $F_2$  folds.

(ii) *Second-generation Mesoscopic Structures:*

The second-generation foliation,  $S_2$ , is a strain-slip (crenulation) cleavage, totally penetrative on the mesoscopic scale, but microscopically, tending to be restricted to definite discrete domains. It is statistically parallel to the axial surfaces of  $F_2$  folds. The mesoscopic  $F_2$  folds are small, with an average distance between hinges of about 1 ft, but hinge spacing of up to 3 ft has been noted. It is not unlikely, as will be discussed later, that  $F_2$  folds have been developed on a macroscopic scale. Mesoscopic  $F_2$  folds are found in all rock types, and lithology seems to have exerted a quite considerable control on the style of the fold. In medium

FIG. 16— $F_2$  Fold Styles.

- a.  $F_2$  Fold in phyllitic greywacke, with  $S_0$  as the form surface, Mt. Blowhard. (Blowhard Style.)
  - b.  $F_2$  Fold, parallel style, in hornfelsic greywacke, Snowy Ck. West.
  - c. Magorra Style  $F_2$  Fold, Magorra Gap, Mitta Mitta.
- All drawings  $\times \frac{1}{10}$ .

textured greywackes, the folds have an almost ideal parallel style (Fig. 16a, b) with hinges varying from rounded and open, to cusped. Cleavage is absent from these folds, the form surface of which is  $S_0$ . The folding mechanism was obviously flexural slip. In many examples of folds of this style, recognition as  $F_2$  structures was not certain unless they contained deformed  $L_1$ , and/or their geometry was strongly discordant to the  $F_1$  geometry. Pl. 29, fig. 2 is an example of one of these folds which does contain a faint deformed  $L_1$ .

Because  $F_2$  folds of the same style are found typically in certain areas, local names have, for convenience, been given to these styles which reflect primarily lithology and degree of deformation. The *Blowhard Style* is a parallel fold developed in greywacke as a result of flexural slip. The form surface is  $S_0$ , and imposed foliations are usually absent (Fig. 16a, b, and Pl. 29, fig. 2). The *Feathertop Style* is found in the finest phyllites (Pl. 27, fig. 2); the hinges are well rounded, and the form surface is the slaty cleavage  $S_1$ . There is a closely spaced axial plane strain-slip cleavage,  $S_2$ , on which folding occurred by slip. This cleavage becomes a totally penetrative foliation in cases of extreme deformation and the fold becomes indistinguishable from  $F_1$  styles. The *Tawonga Style* folds (Pl. 28, fig. 2) are comparable to the Feathertop style, but are restricted to chlorite-quartz-albite schists. There is a widely spaced axial plane strain-slip cleavage; the form surface is a lithological layering tentatively identified as  $S_1$ . *Magorra Style* folds have been described by Hills (1963) as fold mullions. The form surface of the rounded folds may be  $S_0$  or  $S_1$ , and folding was by slip on the axial plane strain-slip cleavage  $S_2$ . This style of fold is normally found in fine, oscillatory graded siltstones. *Snowy Creek Style* folds (Pl. 28, fig. 1) have sharp but rounded hinges, with  $S_2$  restricted to the actual axial planes of the folds. The form surface is  $S_1$ , and the folds are found only in the coarser phyllites. *Harrierville Style* folding (Pl. 29, fig. 1) is found in very fine textured greywacke type rocks and phyllites. The folds are gentle flexures of  $S_0$  or  $S_1$ . Often, as in the figured example, the intersection of the two generations of linear structures has produced a lozenge pattern on the form surface. Deformation appears to have resulted from slip on  $S_2$ , and flexural slip of the form surface.

Second generation lineations and linear structures,  $L_2$ , are of four main styles: fine microcrenulations in  $S_0$  and  $S_1$  of phyllites, angular crenulations, spaced at  $\frac{1}{4}$ " to  $\frac{1}{2}$ " intervals in the less fine textured rocks, cleavage and fold mullions, and rodding. The best example of rodding was observed at the Sambas Mine, Harrierville. The quartz rods have been imperfectly formed parallel to the  $F_2$  fold hinges. They were found only in slates and phyllites, and owe their origin to segregation of quartz from these rocks. Similar structures, on a microscopic scale, have been recorded from near Beechworth (Beavis 1964c).

$F_2$  folds and their lineations plunge steeply, in marked contrast to the plunge of the  $F_1$  structures which is almost invariably gentle. Plunge ranges from  $40^\circ$  to vertical, with  $75^\circ$  to  $90^\circ$  most common. The axial surfaces are usually planar, and the hinge lines rectilinear, at least on the mesoscopic scale. There is evidence from the Mitta Mitta region that macroscopic  $F_2$  folds have curvilinear hinge lines.

### (iii) Third Generation Mesoscopic Structures:

It is known that a third generation of folding has occurred locally in the Beechworth District, associated with plutonic intrusive activity (Beavis 1964c). During the present work, further evidence of an  $F_3$  folding has been obtained, but it is apparent that, while the  $F_2$  deformation was regional, the  $F_3$  occurred only locally near batholiths and major faults. Four separate styles of  $F_3$  folds have been recorded, and, as with the  $F_2$  folds, style has been controlled largely by lithology.



*Mitta Mitta Style* folds (Fig. 17b) occur only in fine slates, phyllites, and microlaminated chlorite-quartz-albite schists, and to date have been noted at only two localities: near the junction of Snowy Ck. West with the main stream, and near the head of Swift's Ck. In both cases they are associated with major faults. The folds are chevron style, identical with the Shotover folds described by Wood (1963) from the Otago Schists. The folds have sharp, angular hinges, with steep axial surfaces. The axial surfaces are open fracture cleavage planes,  $S_3$ . Axial plane separation is unequal, ranging from a few inches to 3 ft.

The *Murmungee Style* folds are also chevron folds, but these are restricted to hornfelsic greywackes and schists in the contact zones of granitic batholiths. The profiles are sharply angular, and there is a well defined axial plane strain-slip cleavage. This cleavage, which is usually developed in one set of limbs only, appears on earlier foliation surfaces as bands of linear structures (Pl. 28, fig. 3). Intersection of  $S_3$  by earlier formed  $S$  defines a lineation  $L_3$ . A rare  $F_3$  fold is the *Wandiligong Style* (Fig. 17a), which was observed only in the Upper Ovens Valley. Bend-glide and shear have been the folding mechanisms, and there is no obvious systematic development of  $S_3$ . Any cleavage is a shear structure restricted to the hinge zone of the fold. There is no true axial plane  $S_3$ .

The *Hotham Style* folds lack the angularity of the other  $F_3$  styles. They are extremely small, and might be more properly regarded as linear structures (Pl. 30). They are found only in phyllites and phyllitic slates. The hinges are rounded, and the size of individual folds rarely exceeds  $\frac{1}{4}$ ". Pl. 30 shows also the multiplicity of lineations in the rocks which have suffered all three deformations.

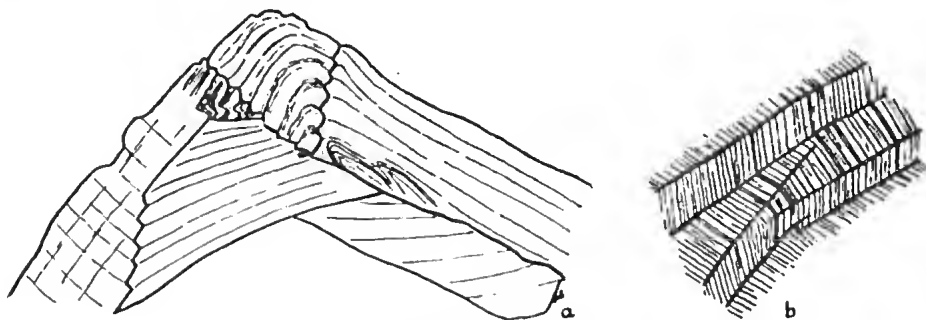


FIG. 17— $F_3$  Fold Styles.

- a. Wandiligong Style Fold, Wandiligong.
  - b. Mitta Mitta Style Folds in phyllites, Snowy Ck.
- Drawings  $\times \frac{1}{4}$ .

Three foliations and associated lineations have also been recorded from the Orbost area (Beavis 1965). In chlorite-quartz-albite schists, transposition of bedding and earlier foliations is clearly seen, producing  $F_3$  folds as small, hook-like structures.

Hoepfner (1956) and others have shown that it is possible for  $F_2$  folds to pass into  $F_1$  folds as a result of continued deformation:  $S_2$  becomes microscopically totally penetrative. The only example of this noted during the present study was in a small area near Tawonga South. Generally non-parallel  $L_1$  and  $L_2$  are ubiquitous in the pelites, with  $L_1$  invariably deformed. Where no imposed foliation, or only a single foliation, is associated with this lineation pattern, the two lineations of themselves are insufficient evidence of two deformations. Where  $F_2$  style folds occur,

$L_1$  is invariably deformed, and curved around the hinges of the  $F_2$  structures. Where  $F_1$  and  $F_2$  folds occur together, the hinge lines and axial surfaces are non-parallel, and  $S_1$  is often the form surface of  $F_2$ , and is clearly older than  $F_2$  (Fig. 18).

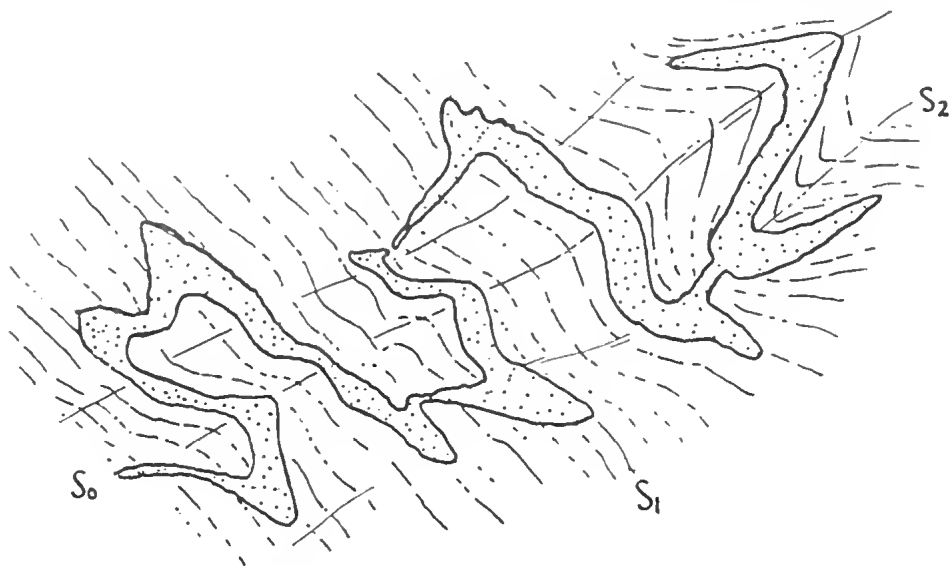


FIG. 18— $F_1$  and  $F_2$  Folds, Rene's Lookout, Hotham Heights.  $\times \frac{1}{2}$ .

Similarly, where  $F_3$  structures occur, they overprint  $F_1$  and  $F_2$  structures, deforming further these earlier folds, foliations, and lineations. There is a marked difference in style of the structures as can be seen from the descriptions above, and the geometric discordance is invariably strong.

In addition to the mesoscopic evidence of multiple deformation, there is microscopic structural and petrological evidence. Non-parallel quartz and mica girdles (Beavis 1964c, 1965; Leggo 1965) must be regarded as valid evidence. Tattam (1929), Crohn (1949), and Beavis (1962a) have all commented on certain retrograde aspects of the mineral assemblages in the schists. It is not unlikely that retrograde activity was due to post progressive metamorphic stressing. It is possible that the first folding and the syntectonic metamorphism are of Benambran age, but the timing of the second and third deformations is unknown. In particular, the third episode may have taken place at different times in different places, so closely related are the  $F_3$  structures to batholiths and faults which have a wide range of ages.  $F_2$  structures are certainly post-metamorphic.

#### MACROSCOPIC STRUCTURES

##### FOLDS

The Ordovician rocks of western Victoria are folded into brachy-anticlinoria and brachy-synclinoria. In central Victoria, detailed mapping has shown that Siluro-Devonian sediments have been deformed into long, continuing structures. In Eastern Victoria, the definition of the macrofolds has not yet been possible, so that the type of macrofolding is unknown. Palaeontological and stratigraphic mapping is not possible in the Ordovician rocks of Eastern Victoria, although lithological mapping currently in progress in the Ensay area by G. W. Williams may be

successful in defining macrofolds. Such mapping in the Harrietville region suggests a comparable macrofolding to that of Western Victoria, but the results are not really convincing. The only macrofold in the Ordovician rocks of Eastern Victoria for which there is any real evidence is the Kiewa Anticline (Beavis 1962a). This structure, determined in schists and gneisses by the analysis of structural elements appears to be a long open fold, plunging gently N. with the W. limb sheared out on the West Kiewa Thrust, and the core occupied by biotite-sillimanite gneiss. The fold is overturned to the W.

In the 'sediments' of Eastern Victoria, the only evidence for macrofolds is the persistence of dip in one direction over wide sections, without reversal of grading in beds.

Leggo (1965) has suggested folding into anticlinoria and synclinoria in the Beechworth-Myrtleford area, using this type of evidence. Leggo admits, however, that his interpretation is highly conjectural.

The idea of determining macrostructure using the 'vergence belt' concept which Wood (1963) applied successfully to the Otago Schists, has been considered, but at present the data are inadequate. The attitudes of bedding and  $S_1$  and the purely localized inversion of gradation preclude any possibility of large recumbent folds. It is highly significant, however, that there appear to be well defined belts in which vergence of the mesoscopic  $F_1$  folds is consistent; e.g. in the Kiewa, Omco, Mitta Mitta and Tambo regions, vergence is westerly, while in the Yackandandah, Talangatta and Nariel regions it tends to be easterly.

The possibility of macroscopic  $F_2$  folds cannot be excluded. The Magorra Gap, near Mitta Mitta, is on a large structure, described by Kenny (1937) which undoubtedly is  $F_2$ , and which approaches the dimensions of the macrofolds of Western Victoria.

## FAULTS

Although determination of faults on stratigraphic evidence is rarely possible in this region, detailed lithological and structural mapping has been successful in locating a number of major faults, particularly in, and about, the metamorphic complex. Virtually all of the faults so far recorded are marked by wide belts of cataclastic rock, both breccias and mylonites. High-angle thrusts, low-angle thrusts, and wrench faults have been recorded.

The Nelse Fault, a sinistral wrench, has displaced the schist gneiss transition on the Bogong High Plains some 14 miles. This fault is marked by a zone of mylonite about 50 ft thick. The Tawonga Fault is of interest because it was initially a dextral wrench, but Cainozoic movement, in which unconsolidated alluvials were involved, was low-angle thrusting. It is this fault which is responsible for the sharp indentation of the E. boundary of the Metamorphic Complex in the Tawonga area. The dominant fault is the West Kiewa Thrust, which forms the western boundary of the metamorphic complex. This fault was previously recorded by the writer (Beavis 1962a) as extending as far N. as Tawonga; evidence has now been obtained which extends it N. to the Yackandandah Batholith, while M. D. Leggo has found evidence of the fault from Yackandandah almost as far N. as the Murray R. It can now be stated that the entire western boundary of the Metamorphic Complex is faulted.

## Discussion

Discussion of the structure may be centred on folds since all of the small-scale tectonic structures are genetically related to the folding. For the Ordovician rocks

of Victoria the following generalizations can be made: folding occurs over the full distribution of the rocks, and all of the folds (with the exception of superposed structures) have a uniform trend. Any deviation from the uniform trend is localized and where changes occur, all the folds are affected. From the evidence of areas in which detailed mapping has been done, it can be stated that anticlines and synclines are equally developed and that both groups in a given area, have the same style and degree of complexity, although lithological differences may cause some modification. On the macroscopic scale there is gradation in the sediments resulting in more complex and tighter folding in the synclinoria, where pelitic beds high in the sequence are exposed, than in the anticlinoria, where predominantly arenaceous Laneefieldian and Bendigonian beds occur.

Of the small-scale structures associated with the folds, axial plane slaty cleavage is particularly informative since with only very local exceptions, throughout the sequence in the Western Trough, it has easterly dip. The axial surfaces of the folds dip easterly at  $75^\circ$ . This is a manifestation of the tendency to a westerly horizontal movement of the folding rock mass. Much of this information is shown on Fig. 19.

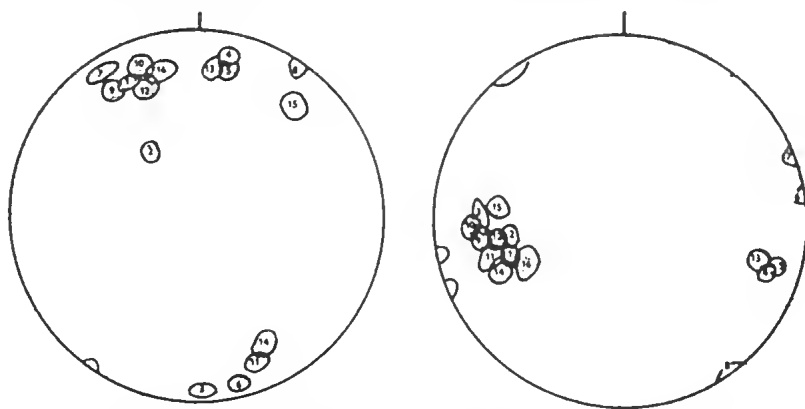


FIG. 19—Projection showing maxima of B lineations, and poles to axial surfaces, for areas of statistically cylindrical folding. Numbers signify common areas.

Consideration of individual mesoscopic folds shows almost invariably a 'similar' style, although where only sandstones are involved there may be some departures from this style. Willis & Willis (1934) introduced the concept of competent and incompetent beds in a folding sequence: incompetent beds were considered to be incapable of lifting any part of the overlying beds, while competent beds were considered to be capable of moving the passive beds and carrying up the weight of the overlying rock. Competent beds would thus transmit the stresses and form the framework of the fold. For the Ordovician rocks of Victoria, it is suggested that this concept is not valid. There has been a redistribution of material in both the slates and sandstones, manifested in a thickening of the hinges and thinning of the limbs in both sandstones and slates. While there is a difference in the degree of redistribution in the two rock types, any rock capable of flow cannot be regarded as a rigid layer which could support other rocks. Rather than relative competence controlling the style and form of folds, it seems more desirable to think of the thickness of the beds and their relative plasticity as constituting the major controls. The thin-bedded slates have formed sharper and steeper folds than either thick-bedded slates or sandstones; thin-bedded sandstones are folded more sharply than

thick. In graded beds, the form of the fold seems to depend on the dominant material.

The formation of the folds is pictured here as a quite complex process in which flexure and bedding-plane slip had only minor roles. Rather, folding was the result of flow in quite plastic sediments, with a marked redistribution of material within the beds. Compression normal to the axial surface is apparent, while confining pressures tended to resist flow parallel to  $a$ , but particularly flow parallel to  $B$ . It was this resistance to flow in  $B$  which resulted in the  $B \perp B'$  triclinic symmetry of the folds and the expression of this as reversal of plunge of  $B$  structures. The principle compressive stresses were E.-W., with an overall tendency to movement towards the W.

The folding seems to have commenced when the rocks were plastic and continued through to the stage when the rocks were quite brittle. In this late stage, fine scale structures, concordant with the main structures, were imposed.

The distribution of assumed and known Ordovician rocks in Victoria is clearly defined: those in Western Victoria extend from near the South Australian border to the Heathcote Axis (the Western Trough) while those of Eastern Victoria extend from Cape Howell westerly to the Dookie-Tatong Axis (the Eastern Trough). Between the Dookie-Tatong and Heathcote Axes (the Central Trough), the only occurrences of Ordovician rocks are those of the Mornington Peninsula, Enoch's Point, the Upper Goulburn and Waratah Bay, some of which may have been faulted into younger rocks. It seems clear that three separate troughs of Palaeozoic deposition existed in Victoria.

Except for a restricted occurrence of Upper Ordovician against the eastern margin of the trough, the sediments and metasediments of the Western Trough are of Lower Ordovician age (or older). In the eastern trough, with the exception of some restricted Darriwilian, the sediments and metasediments are of Upper Ordovician age. It is a reasonable hypothesis that the Western Trough ceased to exist as a basin of deposition near the close of the Lower Ordovician and that the Eastern Trough did not begin its development until very late in the Lower Ordovician. The idea also follows that the Central Trough did not exist until the end of the Upper Ordovician.

#### THE WESTERN TROUGH

As noted early in this paper, the rocks of the Western Trough may extend down into the Cambrian; certainly the most westerly of the fossiliferous sediments are Lancefieldian, and these are situated about the centre of the trough. The unfossiliferous area has associated with it restricted belts of regional metamorphism, and in places, Cambrian greenstones. It might even be considered that the crystalline schists of far Western Victoria are pre-Cambrian basement.

In any case, it is postulated that the Western Trough began its development in far W. Victoria and advanced towards the E. during the Lower Ordovician. By Lancefieldian times, the trough extended laterally from the Heathcote Axis as far W. as Maryborough, but later, in post-Chewtonian times, it was restricted to a narrow, easterly advancing trough, confined between the Muckleford Fault and the Heathcote Axis. At no time was deposition occurring simultaneously over the present width of distribution of the Ordovician rocks. Folding and faulting played an intimate role in the easterly progression of the trough and folding is considered to have occurred concurrently with deposition. Further work to assess variation in sorting, thickness and the existence of minor disconformities is essential to test fully this hypothesis.

Metamorphic rocks occur only in the western half of the trough and are usually associated with granitic intrusions. The metamorphism is not, however, a local contact type, but there is strong evidence of regional metamorphism with transposition on penetrative foliations and lithological layering due to metamorphic differentiation. Little is yet known of these metamorphic rocks, but some, at least, may represent deep burial on structural lows just as greenstones are exposed on structural highs.

There is some evidence from Stawell, Mostyn and Charlton that the metamorphic rocks have small folds superposed on the main structures, but this does not appear to be general, and in fact, throughout the Western Trough it is clear that the rocks have suffered only a single regional folding. The only superposed folding is quite local: Stawell, Mostyn, Charlton, Maryborough, Harcourt and Anakie where later faulting and forced intrusion have occurred.

The structural evidence of a more or less uniform style throughout the Western Trough suggests a uniform stressing. If the hypothesis of an advancing basin is valid, then a more or less continuous folding throughout the Lower Ordovician must be accepted.

#### THE CENTRAL TROUGH

In the Mornington Peninsula there is an almost complete sequence of Ordovician rocks through from Lancefieldian to Bolindian, the total thickness exceeding 15,000 ft. Elsewhere in the Central Trough the exposed Ordovician rocks are of Darriwilian or Upper Ordovician ages. The Mornington sequence suggests deposition in a small isolated basin. Elsewhere in the Central Trough, it may be that no Ordovician deposition occurred. It is known that the trough is occupied by an immense thickness of Silurian and Devonian sediments. The possibility that sediments are underlain by Ordovician rocks cannot be excluded.

#### THE EASTERN TROUGH

Graptolites from high in the Lower Ordovician have been recorded from Myrtleford and Gibbo; all other graptolites recorded from this trough are Upper Ordovician forms. This virtual absence of Lower Ordovician suggests that the trough did not develop until very late in the Lower Ordovician.

It is generally accepted that the trough broke up in the epi-Ordovician Benambran orogeny, with small isolated basins of deposition persisting until mid-Devonian times. This trough, like the Western Trough, can be regarded as one of short duration. Its dimensions are similar to those of the Western Trough and the structures are comparable. It is not possible, with a complete absence of stratigraphic data, to determine the history of the trough, other than in outline. It is quite clear, however, that there was a regional superposition of second generation folds and cleavages and a local superposition of third generation structures.

#### Conclusions

It is postulated that two major troughs of deposition and deformation developed during the Ordovician in Victoria. The Western Trough began its development in far Western Victoria, possibly in Cambrian times, and advanced easterly, reaching its maximum development early in the Lower Ordovician and virtually ceasing to exist in the Upper Ordovician. Deposition and deformation were almost contemporaneous. The Eastern Trough did not begin its development until very late in the Lower Ordovician and broke up at the end of the Upper Ordovician. Between these two troughs was the Central Trough in which only small isolated Ordovician deposition occurred. Its main development was in the Silurian and Devonian.

The style of structures in the Eastern and Western Troughs is the same, but regional superposition of second generation structures, typical for the Eastern Trough, has not occurred in the Western Trough. There is no evidence in the Eastern Trough to show whether folding was continuous and contemporaneous with deposition as there is for the Western Trough.

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### Explanation of Plates

#### PLATE 23

- Fig. 1—Strain slip cleavage in sandstone, Steiglitz, showing conjugate pattern.
- Fig. 2—Cusate structure at base of sandstone, Hanover Fault, Steiglitz.

#### PLATE 24

- Fig. 1—Lozenge structure in sandstone, Anakie.
- Fig. 2—Fine crenulations on strain slip cleavage in sandstone, Meredith.

#### PLATE 25

- Fig. 1—Ripple lineation in silicified slate, Steiglitz.
- Fig. 2—Coarse ripple lineation in sandstone, Woodend.

#### PLATE 26

- Fig. 1—Change in plunge of fold, Calder Highway, Macedon.
- Fig. 2—Folding in fine sandstones, siltstones and slates, Morrisons.

#### PLATE 27

- Fig. 1—Mesoscopic  $F_1$  fold in phyllite, Mt. St. Bernard.
- Fig. 2—Mesoscopic  $F_2$  fold in phyllite, Mt. Feathertop. This fold is the type Feathertop Style. ( $\times 2$ .)

#### PLATE 28

- Fig. 1—Mesoscopic  $F_2$  (Snowy Creek Style) fold in phyllite, Snowy Ck. West, Mitta Mitta. ( $\times \frac{1}{4}$ .)
- Fig. 2—Mesoscopic  $F_2$  (Tawonga Style) fold in chlorite-quartz-albite schist, Symmonds Ck., Tawonga South. ( $\times \frac{1}{4}$ .)
- Fig. 3—Lineations  $L_2$  in  $S_1$ , with  $F_3$  conjugate structures in upper left, Granite Flat.

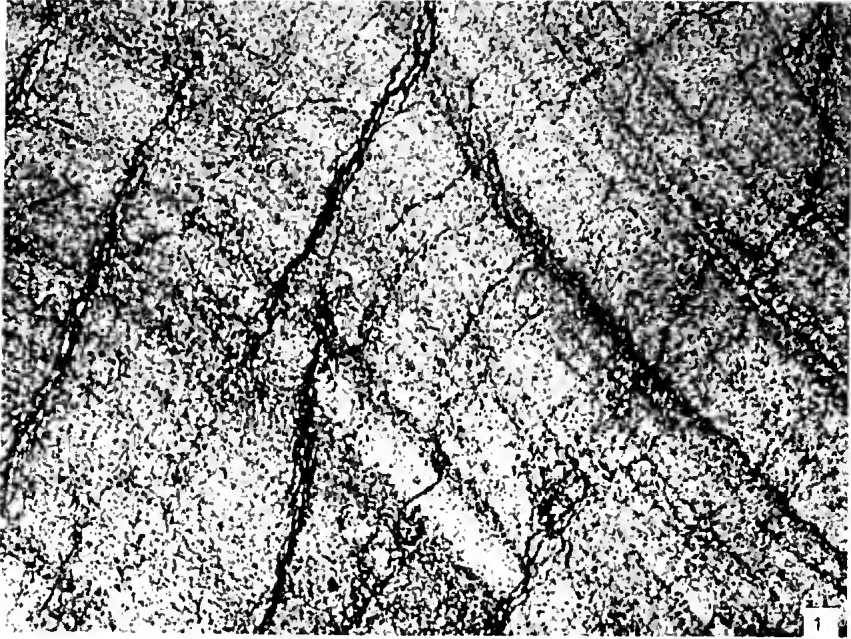
#### PLATE 29

- Fig. 1—Mesoscopic  $F_2$  (Harrietteville Style) fold in phyllite, Omeo Highway, Mitta Mitta. ( $\times \frac{1}{10}$ .)
- Fig. 2—Mesoscopic  $F_2$  (Blowhard Style) fold in metagreywacke, Snowy Ck.

#### PLATE 30

- Mesoscopic  $F_3$  (Hotham Style) folds in  $S_1$  of phyllite, Mt. Blowhard. Note the three generations of lineations present in  $S_1$ . ( $\times 1$ .)



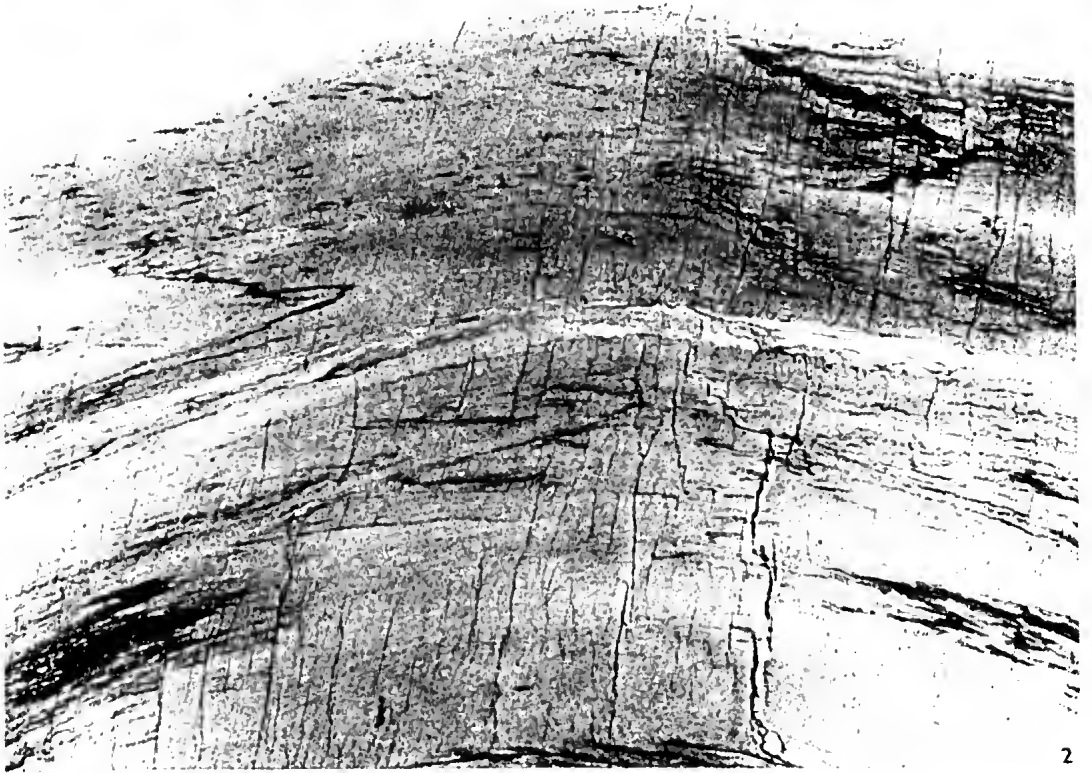


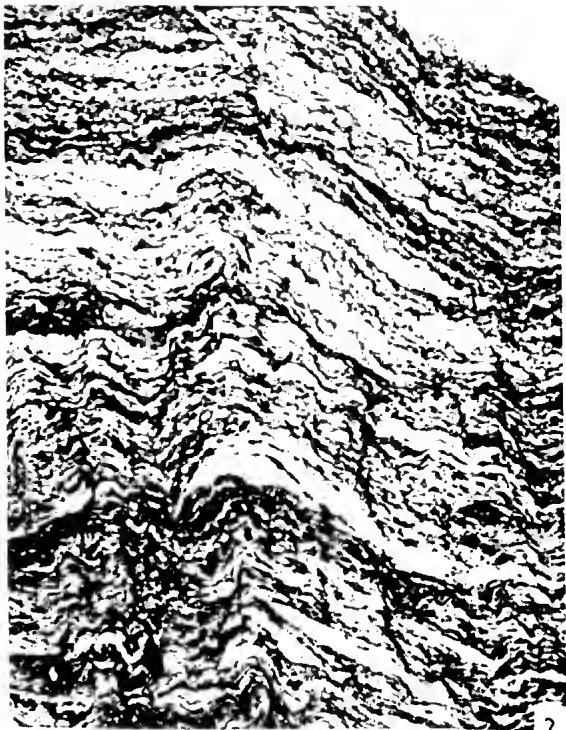


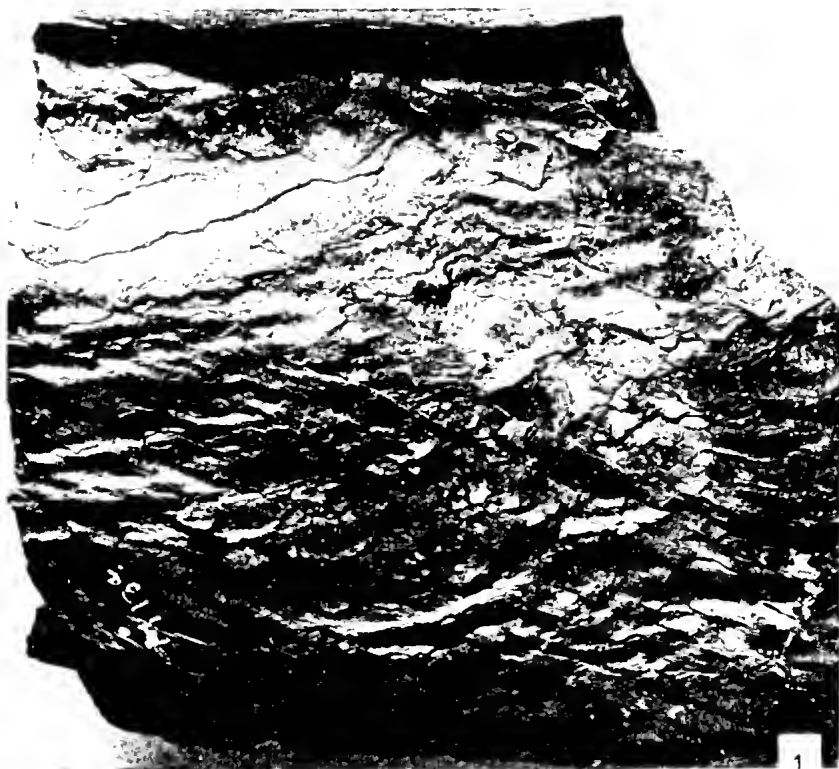
















## THE DYNAMICS OF THE SHORE PLATFORM PROCESS, AND ITS RELATION TO CHANGES IN SEA-LEVEL

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### Abstract

Sea-level is constantly fluctuating and consideration is given to the effect of this on the land/water interface, i.e. on coastal geomorphology. Soft rocks such as sand and clay are graded to present sea-level in the form of a gently inclined plane—the ultimate profile. Conversely, shore platforms occur above low water level in hard rocks. On the S. Gippsland coast an example is taken to show the different platform levels as a function of lithology. If this hypothesis be correct, then something of the history of recent sea-levels can be read from the coastal morphology of the hard rocks. The main point of the paper is to stress the dynamic nature of the shore platform process, as a result of the mobility of sea-level in the Quaternary.

### Introduction

Although there is an important sense in which ‘the present is the key to the past’, there is another sense (also important) in which this is not true, because the Quaternary is quite different from all or most previous geological periods. One of these differences is the immense glacioeustatic changes of sea-level, one result of which is that the margins of the continents have passed through the strongly erosive wave zone, not once, but a number of times. The transgression of the sea from far out on the continental shelf to inland of the present shore in a number of erosive sweeps has created a ‘plain of marine denudation’ of exceptional width.

For the present purpose it should be noted that the migrations of the land/water interface at relatively high speed to and fro across the continental margins means that shorelines are mobile and their structures ephemeral from the point of view of geological history. Most shoreline features are novelties. The shore platform is a process rather than a condition; the function is not static but dynamic. Instead of viewing the shore from the viewpoint of our own short lives (or more accurately, our own short memories), we should undoubtedly think in terms of a dynamic geomorphic process. What we see is but a phase in a series of rapid changes; the milieu is an evolutionary one.

The beach we visit may appear the same this summer as last summer, but if we measure it, we discover this is not so. Not only is much of the morphology new, but also much of the material. Sand contained in the beach last summer has been blown into dunes or washed away by longshore currents. There is a sand budget with the period of changeover differing according to the dynamics of the site. Similarly, the rock platform that in a general way seems the same as a year ago is found to be different if measurements are taken. The sum of such differences over a century is appreciable.

Thus it is proposed that the height of a shore platform is a balance between a number of active factors, viz. the resultant of:

1. The oscillations of sea-level.
2. The nature of the rocks forming the shore.
3. The effectiveness of marine erosion at that site (including waves, chemical solution, spray, and marine life).

4. The climate of the area, and so the nature of the subaerial erosion.
5. Other factors (including the water table).

The process is complex, so any theory involving only one factor is inadequate. The above factors will be examined in the course of the paper.

### **Sea-level is Mobile**

Radioecarbon dating has shown that the glaciations of the northern and southern hemispheres (within its time-range and so presumably throughout the Ice Age) were contemporary, and that sea-level changes were in phase with changes in the world's ice budget. Growth of ice caps meant lowering of sea-level, and melting of the ice caps meant rise in sea-level. The major component in present sea-level change is therefore glacioeustasy. But the ice regime is constantly changing, and so sea-level also is constantly changing. In addition there are the slower changes brought about by sedimentation in the sea, by flexing of ocean floors, and by continental tectonics, besides the expansion and contraction of the water itself with change of temperature. The general acceptance of the mobility of sea-level is very recent, and so all its implications have not yet become clear. In this paper it is suggested that it has implications for shore platform formation.

Following the low sea-level of the Last Glacial, the sea rose rapidly. This Flandrian Transgression was not a straight rise of sea-level. Oscillation has been superimposed upon oscillation. Short-period changes have been superimposed on the effects of major climatic changes such as the Alleröd. Some claim that since the Flandrian Transgression brought sea-level to its present height, sea-level has stood still. If this is meant literally, then it is incorrect, because sea-level is too mobile for that. Fairbridge (1961) has hypothesized a series of sea-level changes through the past 5,000 years; some have claimed that he postulates too many oscillations, but from the point of view of the principle of a mobile sea-level, there are not enough. Tide-gauges, shoreline morphology, and other data show that the contemporary sea-level is mobile, and this has undoubtedly been its condition during and since the Flandrian Transgression. A mobile sea-level is a Quaternary characteristic.

Now this has important implications for shore platforms. If sea-level be as mobile as this, then only the platforms in soft rocks will be fully adjusted to contemporary sea-level, while the cutting of platforms in hard rocks will lag behind. This could account for much of the observed differences in the levels of rock platforms, because it is the hard-rock ones that are more emerged and the soft-rock ones that are less emerged. Other factors being equal, the elevation of shore platforms is a function of lithology.

### **Lithology Affects Development**

On the same coast, under the same conditions of climate and marine attack, shore platforms nevertheless exist at different heights above LWL. This is believed to be a function of differential lithology. For example, on the coast of eastern Victoria, between Inverloch and Cape Paterson (Pl. 31-34), there are platforms consisting of mudstone, others of sandstone, and yet others that have areas of sandstone turned to ironstone by secondary deposition of red iron oxide. A survey showed that the height of the platform was a function of the resistance of the rock to erosion. Thus at the west end of Venus Bay near Inverloch where a sandy coastal barrier gives way to the cliffs of Cretaceous freshwater sediments, the lithology of the shore platform is mudstone and it is graded to sea-level in the same way as the contiguous sandy beach. However, many large concretions caused by

deposition of secondary carbonate occur there in the shore platform and in the cliff. These stand above the shore platform, holding up erosion, and by differential erosion they also jut out of the cliff. A couple of concretions about 2 ft in diameter were broken off along lines of weakness—cracks infilled with calcite. The small point on the coastline at this place is a result of the slowing down of erosion by the calcitic concretions.

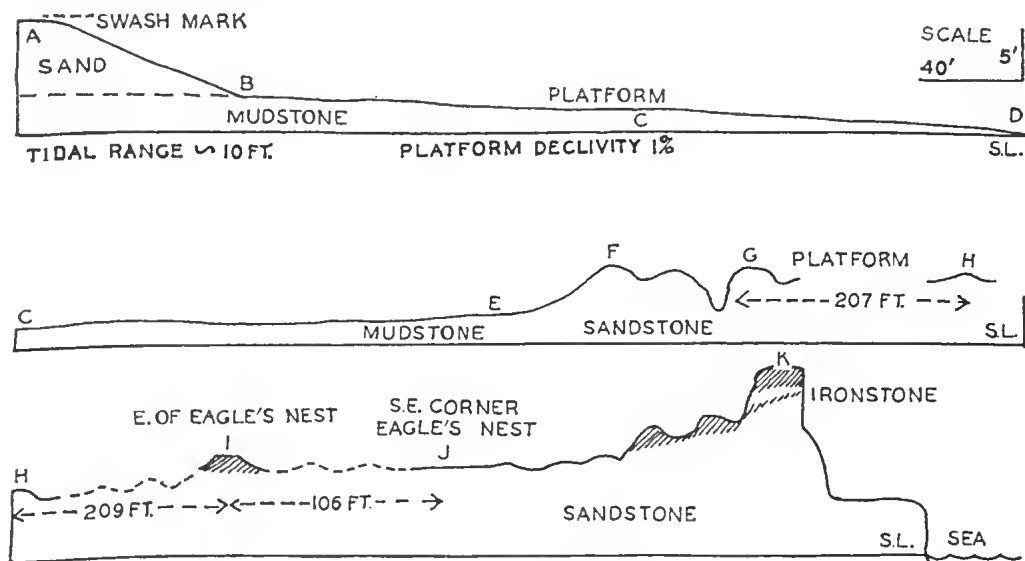


FIG. 1—Three successively higher shore platform levels at Eagle's Nest, Cape Paterson coast, E. Victoria, in Lower Cretaceous mudstone, sandstone, and ironstone respectively.

Section A-D surveyed normal to the shore from the beach swash mark to low water mark. The lithology is stratified mudstone striking in the direction of the section.

Section C-H surveyed from point C in the middle of Section A-D, and traversing approximately parallel to the shore. The change of level between E and F is coincident with the change in lithology from mudstone to sandstone.

Section H-K is a continuation of the Section C-H to Eagle's Nest islet. The changes of level in the vicinity of I and K are coincident with the occurrence of ironstone. In these areas the sandstone is impregnated with red iron oxide. High ramparts as at K are not always at the outer edge of the platform, but may occur wherever there is sufficient ferruginization to make the rock more resistant to erosion.

Eagle's Nest is a small island or large rock stack (Pl. 32, fig. 2) off a prominent point on this coast, the general character of which can be seen in Pl. 31, fig. 1. On the east side of Eagle's Nest there is a platform of mudstone about 300 ft wide with a pocket beach (sand) at the landward end. A survey of this platform normal to the shore is shown in Fig. 1. Where surveyed, there was a fall of 3.16 ft in the 294 ft of the platform from the seaward edge of the sand to low sea-level (B-D), a declivity of about 1 per cent. The platform is smooth except for fine ridges resulting from slight differences in hardness and/or toughness. The strike is normal to the shore, but the same kind of platform occurs where the strike is parallel to the shore (Pl. 31, fig. 2). From the middle of the platform (C), a traverse line was surveyed approximately parallel to the cliffs and about three chains from them. Fig. 1, C-G, shows the abrupt change with change of lithology from mudstone to

sandstone. Whereas the mudstone platform is more or less even, the sandstone platform is very dissected—clear evidence that it is in process of being reduced to a lower level. Near Eagle's Nest, and particularly on the seaward side of it, the sandstone is slightly hardened by impregnation with yellow iron oxide, but the really resistant rocks are those impregnated with red iron oxide (Pl. 32, fig. 2; Pl. 34, fig. 1). It appears that the yellow iron oxide is due simply to the oxidation of the country rock while the red iron oxide is secondarily introduced.

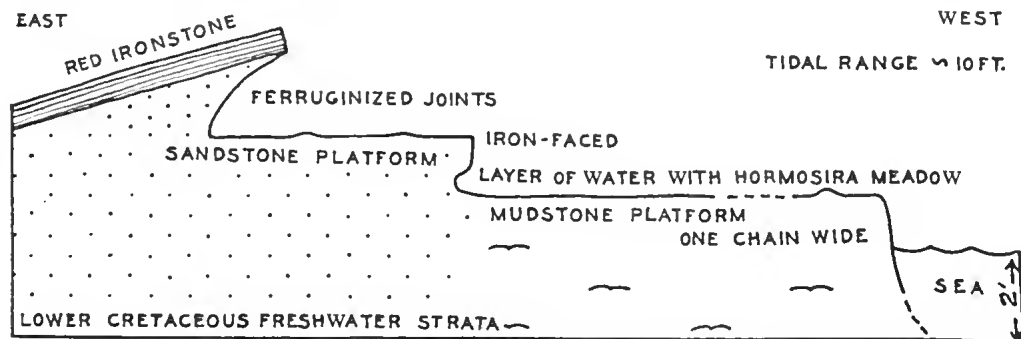


FIG. 2.—Section of shore platforms on the west side of Eagle's Nest, Cape Paterson coast, Gippsland, Victoria, showing the effect of lithology on platform height.

Fig. 1, C-K, shows the effects of competence on platform cutting on the E. side of Eagle's Nest. The low platform in mudstone is succeeded by a higher one in sandstone, and then higher outcrops again controlled by the presence and disposition of rocks with red iron oxide. The same effects of lithology can be seen in microcosm in places where the mudstone is conglomeratic (cf. Pl. 33, fig. 2). The pieces of included sandstone stand up above the mudstone, while fragments of red ironstone stand highest of all. Similar profiles (large and small) occur in vertical section in the cliffs. In Pl. 33, fig. 1, a silicified trunk shows clearly the effects of differential erosion; fig. 2 shows difference in platform level caused by difference in lithology on the W. side of Eagle's Nest.

Similar features to those described can be seen further west near Cape Paterson and at Kileunda. They may likewise be seen in the Mesozoic rocks in the vicinity of Sydney, e.g. at Whale Beach, where there is a sudden drop of level from the sandstone platform to the mudstone one.

### Comparative Lithology of Shore Platforms

When it was noted how important a part lithology played in the genesis of shore platforms, a survey was made of platforms cut in varying lithologies, and the following principles were noted:

1. The softer the lithology, the lower the platform. Conversely, the harder and tougher the rock, the higher it stands.
2. The softest rocks are graded down to present sea-level with a profile similar to that of sandy beach—the 'softest' of the substrates.
3. The low platforms are very even while the high platforms are very irregular. The higher the platform, the more irregular it is.
4. From the foregoing, it is inferred that platforms are in process of being brought into balance with present sea-level. This is readily achieved with soft lithologies but is naturally slower with more resistant rocks.

5. Concomitance of summit level indicates the former presence of platforms at a higher level.

The softest consolidated substrate studied was clay. At Point Henry, at the east end of Corio Bay, Victoria, there is a cliff 50 ft high of clay fronted by a shore platform of the same material. On shallow depressions in the platform there is some soft clay which has been washed from the cliffs. The profile has a declivity of about 1.2 per cent. Seanning by eye gave no evidence of departure from this order of slope. Minor erosion of the platforms continues, but essentially it is in equilibrium with present sea-level. A similar clay platform can be seen at Fossil Beach near Mornington in Port Phillip. The clay at Point Henry is dated as Quaternary by Spenceer-Jones (1963), while the clay at Fossil Beach is Miocene. The former is non-marine and includes pedoecalic soil profiles in three main horizons, while the latter is marine.

Aeolianite (dune calcarenite) presents an intermediate degree of platform reduction about half way between clay and the hard Mesozoic sandstone. The platforms are usually of low declivity and their height above LWM appears to vary according to the resistance of the rock, and the nature of marine attack, but all are below mean sea-level (Gill 1954). Solution and abrasion are both factors in their reduction.

It should be noted that no platform is perfectly even, nor any perfectly horizontal. There are usually two elements in their structure: (1) a seaward slope and (2) a varying amount of surface differentiation. As already noted, the higher platforms are the more differentiated. Shore platform and cliff both show differential erosion, but the cliff is usually more uneven than the platform. The reason is that marine planation smooths many of the protuberances that would otherwise occur in platforms if subaerial erosion alone occurred (Pl. 32, fig. 1).

That gullehes may be cut in shore platforms down to low water mark (or even below) demonstrates how low the sea can cut. Pl. 34, fig. 2, shows such a gulleh eroded where a dyke cuts across the platform on the Cape Paterson coast in Victoria. As the sides of the gulleh are free of marine growth while other surfaces nearby are thickly coated with it, the gulleh sides must be in process of active erosion. Appreciable quantities of marine growth or sediment occur only on the low shore platforms; their absence from higher platforms is due to their active erosion.

### The Ultimate Profile

Given sufficient time, what is the profile to which the sea will ultimately erode a rock platform? It is suggested that the profile established on a beach is the ultimate profile (this term is not used in a technical sense). There the rock (geologists use this term for unconsolidated materials as well as lithified ones) is the most easily eroded of all, and therefore keeps in equilibrium with the forces of the sea. The amount of cut and fill will vary according to the dynamics of the beach concerned, but the gentle declivity seaward is characteristic of beaches. Tidal range affects the angle of declivity, but it is always low. There is a balance between the dynamics of the water and the resistance of the sand (assuming an adequate supply of the latter).

The antithesis often presented between beaches and rock platforms can be misleading. One may grade into the other. It may be noted that where the rocks eroded are very soft, the profile is of the same kind as is found on beaches. Thus at Point Henry in Corio Bay, Victoria, there is a clay cliff and clay shore platform which has a gentle declivity towards the water such as occurs on the contiguous sandy beach.

### Analogous Lacustrine Shore Platforms

There is an analogy between marine and lacustrine shore profiles. For example, at Lake Colongulac in Western Victoria (Gill 1953), mid-Holocene lacustrine shell-beds (Gill 1964), and the overlying windblown clayey silt (parna) are being rapidly eroded by lake waves to form an ultimate profile similar to a marine one. The parna is more easily eroded than the shell-bed, and so a small platform of shell-bed may occur, but this also is gradually reduced to the ultimate profile.

However, where the outcropping rock is basalt, which is too hard to be eroded rapidly, the shore platform emerges. Some of the basalt platforms are comparatively old, e.g. on the SE. side of the lake, shell-beds of the order of 14,000 years old are partly stripped from a basalt platform. Thus although lake level fluctuates (as does the level of the sea), the soft rocks are rapidly reduced to a profile of low declivity in balance with the dynamics of the lake waters (an ultimate profile), while the basalt takes a very long time to be eroded down to the same profile. The emerged basalt platform has nothing to do with storm waves (an explanation given for high rock platforms along the sea shore), but is simply a function of lithology in relation to the dynamics of the eroding waters.

### Rock Structures and Shore Platforms

It has often been pointed out that some rock platforms owe their development to structures in the rocks forming the coast (Jutson 1950; Hills 1940, fig. 284; Edwards 1941). A soft rock can be stripped from a hard one, and so leave a platform. Similarly a weak stratum can be eroded from a compact stratum, or decomposed rock removed from fresh rock; or a zone of rock may be quarried out so as to cause collapse of the overlying rocks and thus develop a platform. Similarly, a fossil soil may be excavated by wave action, causing collapse of the cliff above, and when the debris is cleared by the sea, a platform remains. Likewise, soft calcarenite may be swept from a zone lithified by deposition of secondary carbonates.

Development of a platform may also be affected by the cleavage in a rock formation, by the presence of joint planes, and by the incidence of such planes and of faults—large and small. The tendency to decrepitate on exposure to sub-aerial agencies (especially wetting and drying) is a feature of many siltstones, so that what appear to be strong strata become weak under certain conditions. Likewise rocks vary in their tendency to break up when frozen and thawed, or subjected to salt crystallization. On the Port Campbell coast in Western Victoria, cliffs of Miocene marine limestone occur up to 200 ft high, and face the Southern Ocean, there being no land between this coast and Antarctica. It is thus a high energy coast. The earthy limestone has a vertical cleavage, so that it is common for a fissure to develop which separates off a segment 20 to 30 ft long, as high as the cliff, and five to six ft wide. Rain water pours down such cracks, and further weakens the structure. Storm waves quarry out these gigantic blocks, so that they collapse into the sea, where they are broken up by the turbulent waters. In protected bays they may drop down, still leaning against the cliff. The cleavage does not appear to go further than the level of the narrow shore platform (where present), below which is constantly damp and relatively unoxidized rock.

Highly soluble rocks are naturally affected by the presence of water, and then solubility of the rock is a factor in platform formation. Hodgkin (1964) calculated a mean reduction of 1 mm per year for an acolianite platform in Western Australia.

Thus the lithology of the coastal rocks is a definite factor in shore platform formation, as many authors have indicated.

### Effectiveness of Marine Erosion

If the sea were immobile the only erosion would be by solution. If there were only waves of oscillation they would impinge on the cliff or the vertical wall forming the outer edge of many shore platforms, and be reflected out to sea again, having little (if any) effect. It is the waves of translation (in the sense of breaking waves) that erode, especially when armed with sand and rocks. Thus the outer wall of the platform is covered with organisms, while the surface of the platform is more often than not scrubbed clean except where hollows and scour holes provide some protection, but even there growth is limited. On a high energy coast, large boulders are quarried from the cliffs and litter the sea floor in front of the platform—to the distress of fishermen. They also are covered with marine growth as are the bases of truncated islands and rock stacks.

While solution, water layering (Hills 1949), and such processes operate chiefly at rock platform level and thereabouts, storm waves, salt spray and such agencies operate over great heights. Storm waves on the Port Campbell coast mentioned above, may splash 50 ft above the 200 foot cliffs, stripping the edges in many places (Baker 1958; Ongley 1941). The salt spray spreads further still, drifting inland, and some salt travels hundreds of miles to descend as cyclic salt far from the coast (Anderson 1945). Storm waves exercise their maximum attack at different levels according to tidal conditions, wind force, wave size and incidence, and other factors. Thus to attribute a horizontal platform in a homogeneous rock to storm waves appears unreasonable to the writer.

This argument applies even more to salt spray which attacks the whole coastal facade and the terrain for some distance inland. Even in the climatic conditions that best suit this kind of erosion (Tricart 1959) one cannot imagine a process whereby a level platform is attained, if the rock be homogeneous. On the coast at Goose Lagoon in western Victoria, waves erode the coastal basalt smooth except for well sheltered sites above HWL which may be honeycombed, presumably by salt spray etching. At Whale Beach, N. of Sydney, honeycombing on a much larger pattern is seen high up on the cliff faces, and it appears to be a function of salt spray erosion (cf. Bartrum 1936).

Solution operates on every coast, but to different degrees. All rocks are in some degree soluble. A calcarenite coast may lose much mass by solution, but it may also gain. In hot, dry weather, carbonates dissolved in spray may be soaked up in the lime sand, the water evaporated, and secondary carbonate deposited. In this way the sand is lithified, and resistance to erosion increased. This process has been observed in Victoria on the Sorrento Peninsula and in the Warrnambool district.

### Marine and Subaerial Erosion

Shore platforms occur in the zone of overlap of marine erosion and subaerial erosion. Rain falling on the land seeps through porous rocks or along structural cavities such as joint planes and caves. If the rainfall is high there will be a hydrostatic pressure of water pressing towards the sea. With variations in lithology, season, and climatic cycle, the water-table may be variable. Likewise, as already described, sea-level is mobile. With the variation in the water-table there is variation in the penetration of air, and so also in the processes of oxidation, carbonation, and so on. All three systems of ground water, sea water, and air are dynamic, and their 'eutectic point', so to speak, is at or near the level of the shore platform. Thus the cutting of a shore platform may be related to the base of oxidation in the country rock, or to the level of constant water saturation, as well as to the erosive sea/air interface. But for all three the nature of the country rock is important—its porosity,

its degree of weathering, its diagenesis, and its competence to resist marine attack.

It seems to the writer that there are four important processes at work (but others as well) reducing the level of the shore platform, viz.:

- (a) Chemical weathering (including oxidation, carbonation and the effects of salt). This is particularly significant in humid tropical areas where warm copious waters rapidly rot the country rock.
- (b) Abrasion by the waves, especially when they are armed with sand, rocks, and other abrasive tools.
- (c) Solution, a chemical process at work on all rocks, but particularly effective on carbonates because of their high solubility.
- (d) Wetting and drying, a physical effect noted especially in fine grained sedimentary rocks such as siltstones. Rocks otherwise hard and tough will decrepitate under such conditions and so readily disintegrate. A given rock will develop a characteristic pattern of decrepitation cracks under wetting and drying.

### Genesis of Shore Platforms

Bird (1964) has provided a very helpful treatment of coastal landforms, but he is obviously puzzled about shore platforms. He describes two kinds of shore platforms (for which there may be two kinds of process), viz.:

- (a) Intertidal platforms which are slightly inclined seaward.
- (b) High tide platforms which are horizontal.

Bird's intertidal platform is the ultimate platform of this paper. If there were only 'intertidal platforms' graded to LWL and 'high-tide platforms' graded to HWL, an hypothesis of two processes could be considered, but the fact is that platforms at all levels in-between do occur. The hypothesis advanced here is that all higher platforms are stages in the process of reduction to the ultimate platform.

Bird (p. 52) suggests that storm waves 'are responsible for the recession and dissection of the outer edge of the high-tide platform, particularly along joints and bedding-planes, rather than the planation of the platform itself'. However, it should be noted that such outer edges are usually strongly protected by biologic layers (calcareous algae, seaweeds, barnacles, molluscs, tunicates, etc.), while the platform is comparatively bare, such life as occurs being in protected places. Close examination of the platform shows it is suffering abrasion.

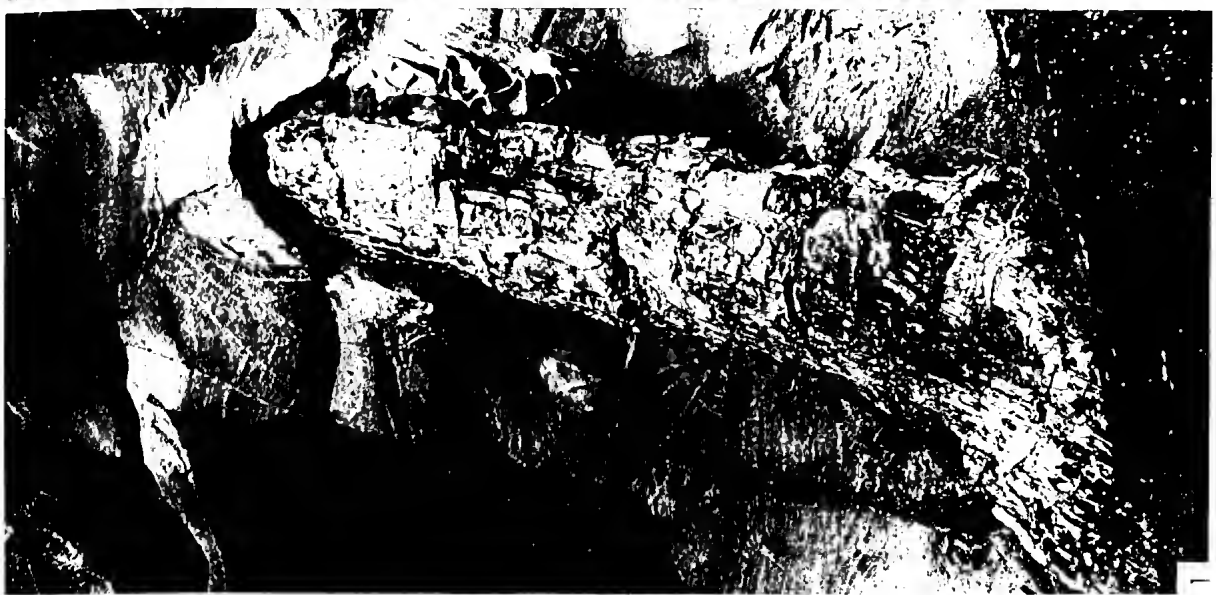
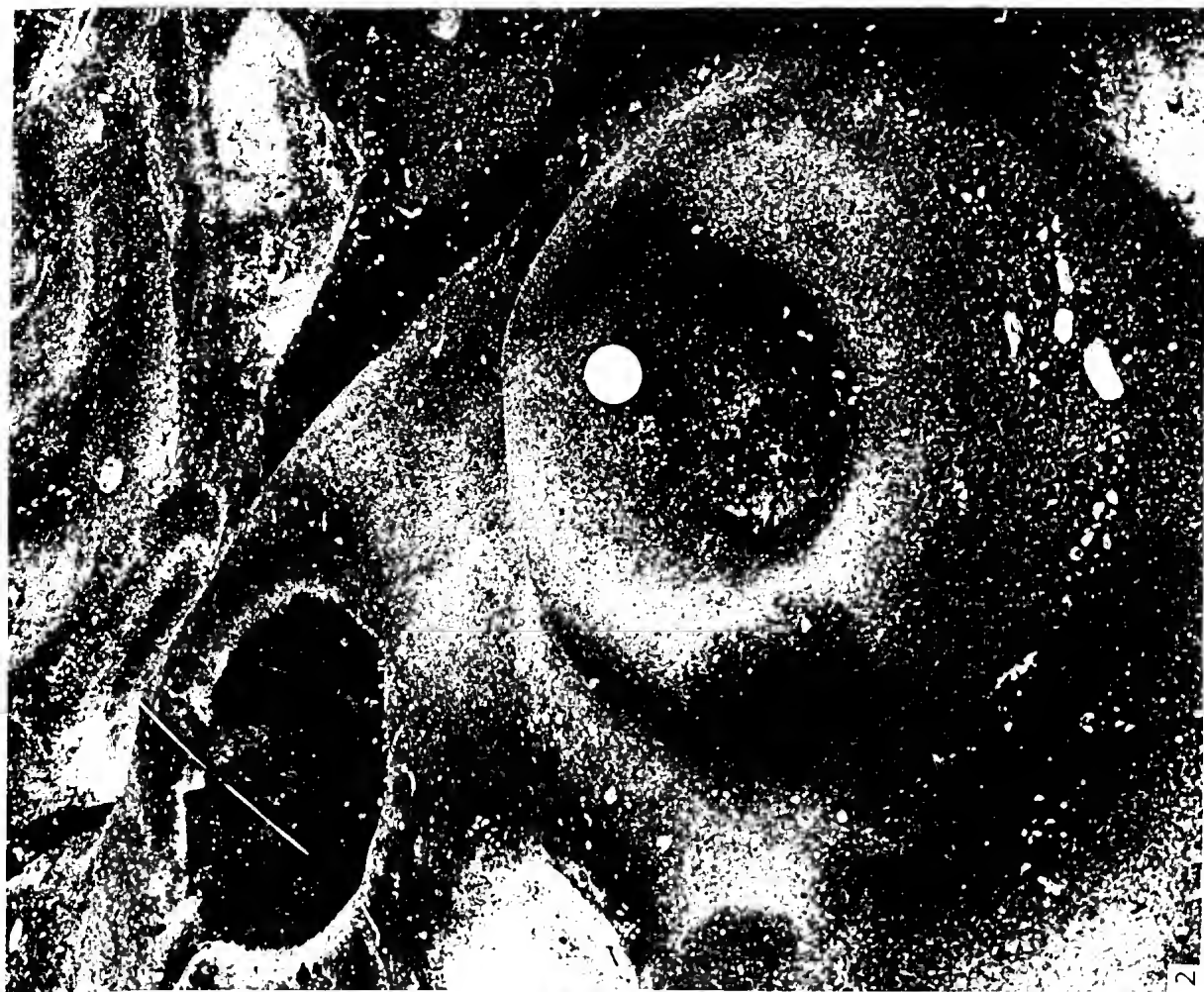
If calm seas erode at one level and storm seas at another, then there should be duplication not only of platforms but also of other features such as the wave-cut nip. I regard the wave-cut nip as the homologue on the rocky coast of the swash area of the beach. In the swash area the waves breaking on the sandy beach dissipate their excess energy. At the wave-cut nip the waves normally expend their excess energy by rolling back on themselves at the nip.

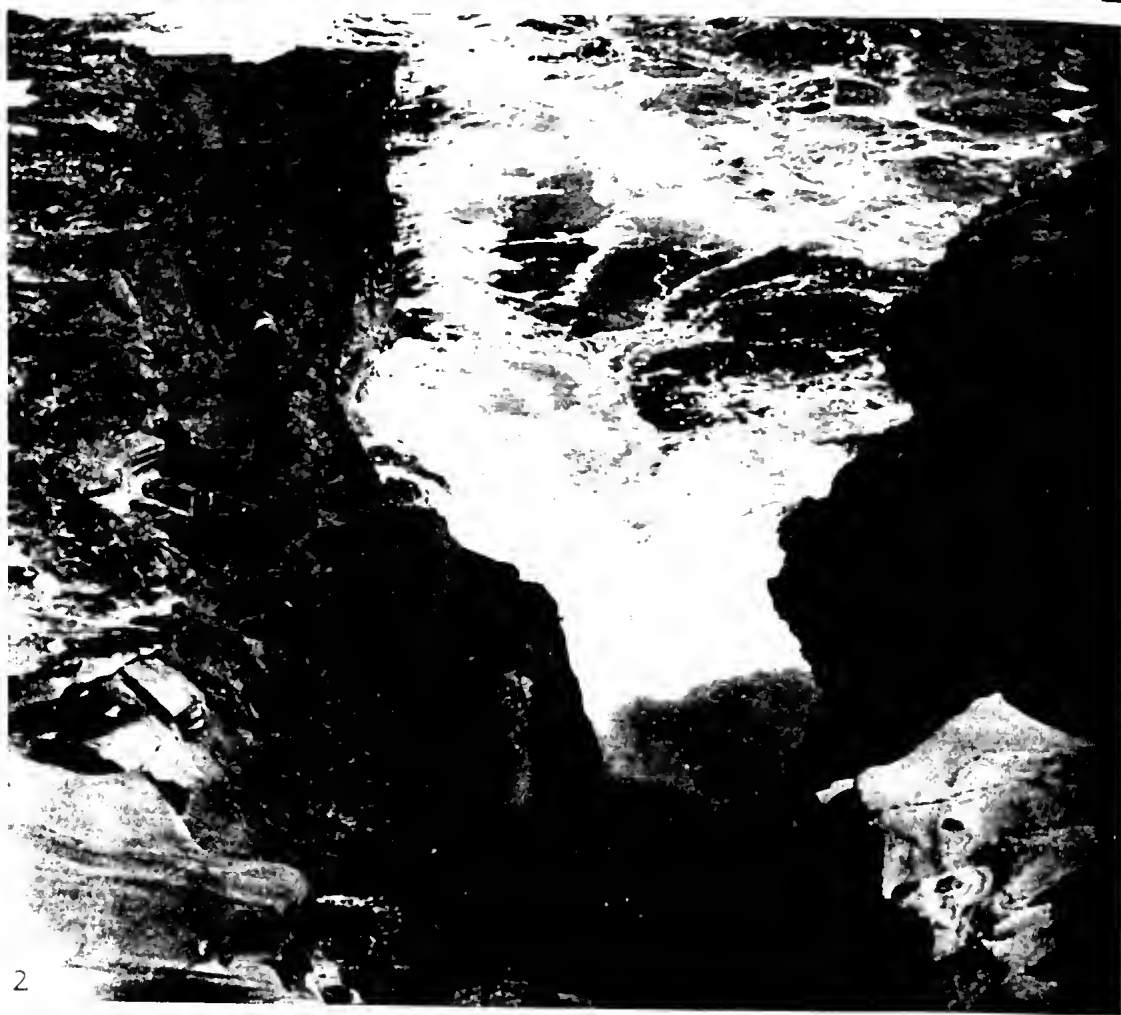
An hypothesis of high and low tide platforms is unable to explain the structures at Eagle's Nest described above where in the space of a few hundred yards there is an 'intertidal platform' and a 'high-tide platform', with other levels in-between, and the differences are coincident with changes in the hardness of the rock. The hypothesis presented in this paper is looked upon as but another approximation, for we are still very ignorant about these processes. However, if it be proved that higher platforms are just those in process of reduction to the ultimate platform, then at some time in the not too distant past the ultimate platform must have been much higher, and this infers a higher sea-level or emergence of continental magnitude.











### Conclusions

A dynamic concept of the shore platform process (rather than condition) is presented. It is a multiple hypothesis, involving a number of factors:

1. The dynamic of constantly changing sea-level. Because sea-level is always changing, only soft rocks are in equilibrium with contemporary sea-level. The thesis is proposed that the higher platforms in harder rocks are a relic of a recently higher sea-level.
2. The dynamic of marine erosion. The physical power of moving ocean waters (especially if armoured with sand and rocks), and the chemical power of these waters to dissolve minerals, results in reduction of the rocks of shore platforms, but the effects vary according to the nature of the substrate.
3. The dynamic of the local subaerial system (climate). The physical and chemical effects of wetting and drying, the temperature and humidity of the surrounding air, the gradients in salt concentration, and other climatic effects also bring about change in the rock platforms and the contiguous cliffs.
4. Other factors also operate, but the above are believed to be the three most important.

The purpose of this paper is to stress the dynamic nature of the shore platform process, and the mobility of sea-level in our current geological era—the Quaternary.

### Acknowledgements

The author is indebted to Dr J. N. Jennings and Dr E. C. F. Bird for making helpful criticisms of this paper.

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## Explanation of Plates

## PLATE 31

- Fig. 1—Looking east from the top of the cliff at Eagle's Nest at approximately mid-tide. The mudstone platform is covered by the sea, but the sandstone one is not covered. The strike of the strata is normal to the shore.
- Fig. 2—Cape Paterson coast. An ultimate platform in mudstone, similar to that at Eagle's Nest (Pl. 31, fig. 1) but with the strike parallel instead of normal to the shore. The strike of the strata does not affect the development of platforms in these mudstones. Shoreward of the platform is a narrow sandy beach.

## PLATE 32

- Fig. 1—Both cliff and platform show differential erosion along the Cape Paterson coast, but the platform is relatively smooth due to wave action removing many of the irregularities that remain in the cliff. The figure stands beside an eight-inch-wide seam of calcite.
- Fig. 2—Rock stack on Cape Paterson coast, E. Victoria, called Eagle's Nest. The shore platform in view is cut in Lower Cretaceous felspathic non-marine sandstone lithified with secondary laumontite. Although the photograph was taken at approximately mid-tide, only the lower mudstone to the left of the photo was covered by the sea, while the higher sandstone platform is still exposed. The highest areas at the outer edge of the sandstone platform owe their elevation to still stronger resistance to marine attack due to their ferruginization. The relative heights of the intertidal platforms here are a function of lithology.

## PLATE 33

- Fig. 1—Cape Paterson coast. Silicified trunk in felspathic sandstone. It lies at an angle of  $45^\circ$ , and appears to be in place of growth. The trunk is about 10 in. in diameter, and is an unusual example of differential erosion on the rock platform.
- Fig. 2—Pothole in sandstone platform in bay immediately W. of Eagle's Nest soon after removal of a concretion by wave action. Note the erosion of a joint plane (on right), the abraded surface of this high platform, and the differential erosion of the included rock fragments round the pothole. Such potholes are commonly white with salt on calm days in summer, i.e. when the waves do not break over while the tide is low, and the sun is warm enough to evaporate the water left in the pothole.

## PLATE 34

- Fig. 1—Cape Paterson coast. Sandstone platform with rampart of ferruginized sandstone at the outer edge. All such ironstone residuals are not on the outer edge of the platforms.
- Fig. 2—Gulch in high sandstone platform on the W. side of the bay immediately W. of Eagle's Nest. The gulch is developed along the interface between a basaltic dyke and the country rock. Note the absence of any appreciable amount of marine growth on the sides of the gulch, showing that abrasion is occurring.



## THE INTERACTIONS OF PLANTS AND ANIMALS ON RABBIT ISLAND, WILSON'S PROMONTORY, VICTORIA

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### Abstract

Rabbit Island was visited during May 1965 in preparation for a study on the interactions of rabbits and island vegetation and the effects upon the breeding of *P. tenuirostris* and *E. minor*. Details of the island and its vegetation are given and the possible stages leading to the dominance of *Poa poiiformis* are discussed.

### Introduction

Rabbit Island was visited from 9 to 13 May and again on 27 October 1965. The island, some 80 ac. in area, lies less than a mile from the north-eastern side of Wilson's Promontory.

This report forms part of a survey presently being undertaken on the interrelations existing between introduced mammals (such as rabbits, sheep, rats and foxes) and island nesting seabirds such as *Puffinus tenuirostris*, the Tasmanian Muttonbird, and *Eudyptula minor*, the Fairy Penguin. It will be the basis for more detailed studies to be pursued there. Reports on the Promontory islands, including Rabbit Island, have been made by Gillham (1961, 1962) who has also discussed the effects of mammals and burrowing seabirds on island vegetation (1955, 1956), but no other reports concerned with the area have been found.

### Physical Structure

The island rises to 194 ft and is a grey granite similar to that found on the adjacent parts of the Promontory. Outcrops of the granite, varying in size, occur over the island though they are not present on the W. side, where a sand-filled 'valley' exists, extending from a small beach up to the centre of the island where it meets with a sand blow across the summit (see Pl. 35).

Erosion gullies, due to the rapid run-off of rain, are found near the summit and along the eastern side. There is a small seepage channel, which is said to form a stream after rain, at the southern end of the beach.

On the E. and S. sides are cliffs, undercut in places by sea caves, but elsewhere the rise from the sea-level to the summit is more gradual.

Protection from the NW.-SW. winds is provided by the Promontory mountains in the vicinity, which reach 2,092 ft (Mt Vereker in the SW.) and 1,050 ft (Mt. Roundback in the NW.). It is this shelter which, together with the local currents, has presumably been responsible for the sand beach becoming established on the NW. side.

### Vegetation

A list of the plants found is given in the Appendix and comparison is made with the list given by Gillham (1961).

The dominant (commonest) species over the whole island, as on many Bass Strait islands, is *Poa poiiformis*. In the extensive rookery areas the *Poa* is inter-

spersed with bare earth patches. The almost pure stand, over most of the island two to three feet high, becomes lower and increasingly interspersed with sand around the eroded area. However, *Senecio lautus* forms a belt along the northern and southern limits of the sand blow and is found in the valley.

Though the *Poa* is overall dominant, small communities of *Pteridium esculentum*, *Urtica urens* and *Carduus tenuifloris* become locally dominant or co-dominant with the *Poa* within the sand valley; *Juncus pallidus* is also occasionally dominant.

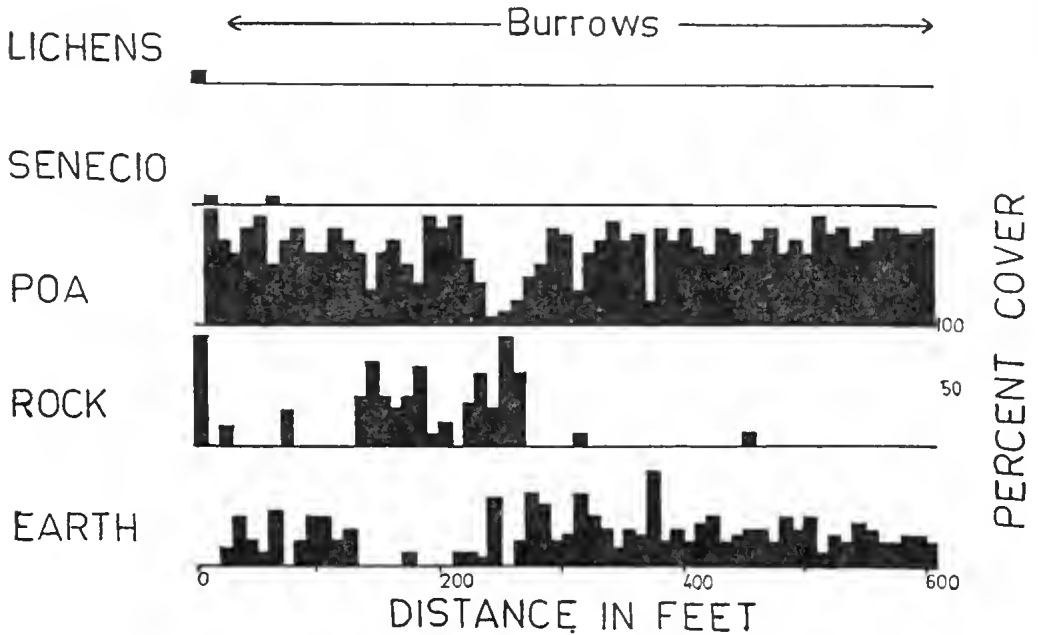


FIG. 1.—Line transect a. From splash zone on west side towards north end (100°). 610 feet long, intervals of 10 feet.

Transects (Fig. 1 & 2) show the overall dominance of *Poa* and the restricted number of species is clearly indicated by transect (a), which was made from the splash zone of the NW. coast, easterly through the rookeries as indicated. Bare soil, a result of penguin and muttonbird activity, occurs frequently across the northern end of the island and the same is true for the southern portion though a transect was not made. In transect (b), *Poa* is dominant again, but it can be seen that occasional communities other than *Poa* do occur. This transect, made from the beach to the summit, also indicates the reduction of vegetation within the sand-blow region, though no rookeries were crossed.

Remains of stumps of *Acacia longifolia*, some charred, indicate that it was at one time extensive over the N. and W. regions of the island. Fires presumably contributed to the reduction. Only a few shrubs, reaching six feet in height, now exist on the summit and at a site on the western side. Those on the summit, behind a sand hummock, lean towards the E. and appear to be mostly dead or dying. Another large shrub, *Leptospermum laevigatum*, was present at two sites (dark patches in Pl. 35) and the smaller *Correa alba* was also found along the W., sheltered side.



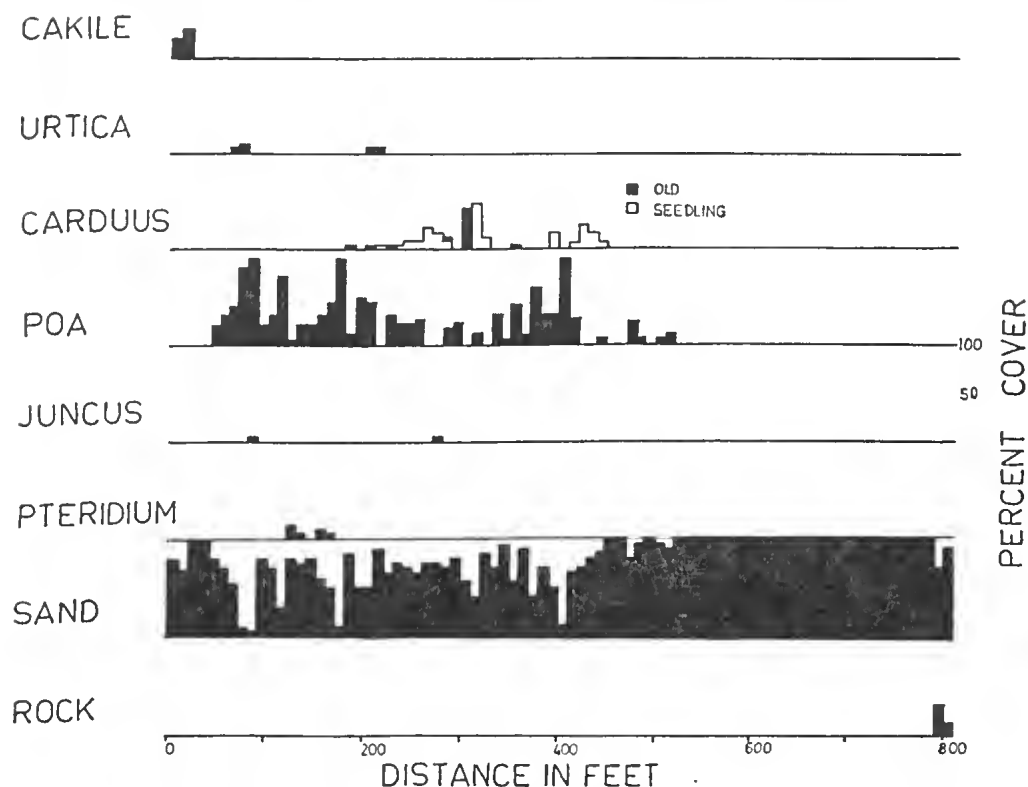


FIG. 2—Line transect b. From HW mark on sand beach to summit (110°). 810 feet long, intervals of 10 feet.

Seedling *Senecio* had become thinly established across the sand blow by the second visit and occasional *Poa* and *Cerastium* had also appeared.

The sand beach is backed by an embryo dune system of pure *Cakile maritima*. Along the rocks, in the supralittoral zone, *Disphyma australe* and *Carpobrotus rossii* are found; these, together with *Stellaria media*, extend high up the cliffs in places. The ferns *Microsorium diversifolium* and *Asplenium obtusatum* are found in rock crevices along the coast.

#### Factors Influencing the Vegetation

The vegetation, an almost pure stand of *Poa* throughout the island, can be considered as being influenced by climatic and edaphic factors and by biotic factors (e.g. rabbits, birds and man). Gillham (1961) states that 'very few subordinates have survived the combination of summer drought, burrowing birds and grazing rabbits on the main part of the island'; the influence of wind should also be considered.

##### (i) ABIOTIC FACTORS

Rainfall, in coastal Victoria, is relatively uniform throughout the year as a result of the prevailing westerlies, although Rabbit Island may lie within a possible rain shadow created by mountains to the W.

Records of wind at the Promontory lighthouse during the period June 1962 to May 1965 show the predominance of westerlies; indeed 50.9 per cent of all winds came from SSW.-W. Bird (1965) considered that 'the minimum wind speed necessary for sand drifting is slightly less than Beaufort scale 4 (about 10 knots)', and so I have analysed the records for winds above 10 knots. Westerlies made up 39.2 per cent of the total in this category. It is of interest that slightly over 50 per cent of the winds recorded during the period were above 10 knots.

Accumulation of humus and charred plant-remains, together with the weathered granite sand, has led to the formation of a dark soil found over most of the island. However, in the valley, the light coloured sand is unchanged and the grain size is large, particularly over the eroded area where a grit, predominantly quartz, remains. Soil samples, taken from inside and outside rookeries, showed a wide range of pH values, from 4 to 7 (by laboratory determination using Universal Indicator at 1:5 dilution). The extremes were both outside rookeries, near the summit and on the east side respectively. Rookery samples were all acidic, having an average value of 4.6. Water retention was low, the average percentage present by weight being only 4.45, and loss of nutrients provided by guano must be high as the result of constant leaching, there being no clay layer.

#### (ii) BIOTIC FACTORS

**RABBITS.** The introduction of rabbits on to islands, in this case in 1836 (Stokes 1846), used to be standard practice, the rabbits supplementing supplies of mutton-birds or fish as a source of fresh food for mariners. The rabbit, which has 'greater ability to utilize very small plants (compared with stock)' (Ratcliffe 1959), is the limiting factor both to growth and to the number of species, since it will feed selectively, conferring upon some plants a 'competitive advantage over others' (Myer & Poole 1963). Added to this is the destruction and denudation of the soil surface. Taylor (1955) has shown that, on Macquarie Island, soil slip and erosion occur on slopes of more than 25°; such an action could have taken place on the eastern side of Rabbit Island as evidenced by the slope of pure sand which inclines at about 45°.

The intense grazing by rabbits would reach maximum importance and have the most noticeable effects during a summer drought where there is no standing water and the run-off stream is said to be below the surface. Hayward's experiments (1961) on the rabbit's ability to withstand long periods of water deprivation, showed that the majority of mortalities occurred about two months after the initiation of the drought period. 'Quite probably starvation, as well as dehydration' were the causes of mortality, according to Hayward; the starvation being caused by 'a decreased food intake brought about by a severely restricted water intake'. On Rabbit Island, reduced availability of water (which may not have been totally absent), together with a decrease in plant growth would limit the number of rabbits which the island could support and the growth and spread of plants would be restricted by the increased rabbit grazing-pressure.

During my visits no rabbits were seen, though Gillham (1961) considered that the 'estimated population (in 1959) there is small in relation to the total area, but large in relation to the amount of available food'. Local fishermen told me that rabbits were present in January 1965, indicating that myxomatosis became established on the island about February 1965, presumably as a result of infection from a source on the mainland. Initial infection would probably have been by a wind-blown mosquito; there being no evidence of intermittent pools present to allow breeding, further spread on the island would probably have been by fleas or sand

flies, both known to be vectors. Myxomatosis, no doubt coupled with the summer drought and the annual food shortage, appears to have been almost completely destructive in this case. Some 150 corpses, estimated to be about two months old, were found, but only one fresh set of droppings and tracks. New growth of all plants examined was found to be completely untouched.

Gillham (1961) worked out the species: acreage ratio from a series of islands around the Promontory and found a close correlation between this ratio and degree of exposure. Rabbit Island (80 ac. with 31 recorded species) and Clifty Island (100 ac. and 39 species) had an approximately equal species:acre ratio. Clifty, some ten miles to the east of Rabbit, was more exposed and she concluded that the effect of spray-bearing winds was to depress the species total, whereas on Rabbit Island 'the number of species was severely depressed by rabbit grazing'.

BIRDS. Gillham (1955) has discussed the influence of trampling, by colonial nesting sea-birds and mammals, on the vegetation of islands. In general, she concludes that 'like grazing and wind action, it restricts the number of species and favours the low-growing or hemicryptophytic habit in plants'. Mutton-birds and penguins have either regular paths for take-off into the wind or tracks for walking up and down a slope. These paths are devoid of vegetation. In the process the binding, originally sub-surface parts of the plants, such as *Poa*, become broken up and destroyed. Given certain conditions this could well lead to erosion, the birds aiding the process by moving the soil downhill.

Mutton-birds and penguins occur in mixed colonies over most of the island. The trampling action of the former is rather limited since the steep slopes make take-off relatively easy. However, burrowing of both species must be an important factor, and in addition the penguins have formed a large path system which starts on the southern end of the beach and radiates out into subsidiary tracks which lead over the island. Such tracks aid the formation of erosion gullies.

MAN. The influence of man on the vegetation has been, and is still, of considerable importance both by the introduction of rabbits and the initiation of fires. Extensive firing of the vegetation, to facilitate the harvesting of mutton-birds, probably removed the original scrub flora, enabling the *Poa* to become dominant. Haydon (1846) mentions that there were rabbits on the island, and that on the 'west side of the island, there are the remains of a hut and garden'. Presumably fire was used to clear the garden area; the island was swept by fire in 1941 and again in 1955 though less severely (A. G. Galbraith, *in litt.*).

### Discussion

The present vegetation of many Bass Strait islands, mostly tussock-grass, suggests that man has been responsible for the removal of scrub species; early records indicate that few islands were without occupants (Plomley 1966). Rodondo Island, about 10 miles to the south of the Promontory, is thought to be an exception. Here there is an extensive scrub flora, including *Melaleuca pubescens*, *Eucalyptus bicostata*, *Myoporum insulare* and *Correa alba* (Bechervaise 1947). He considers that the island has never known human interference. 'It contains several hundred acres which, in that they have never been burnt, are of a quality rare in the Australian bush. The only signs of fire were on two comparatively recent lightning-struck trees from which it was obvious no flames had spread.'

*Poa poiformis* is present and in many areas grows beneath the trees. Thus the vegetation of Rabbit Island could have been one dominated with shrub species in the interior and having a coastal belt of *Poa*. The burning off and introduction of rabbits, which would prevent any regeneration of shrubs, could have led to the

present structure. Wind, with salt spray, must also have been important in preventing a return to the climax. (An interesting comparative situation exists on Great Glennie Island, six miles W. of the Promontory, where the vegetation on the N. end is largely *Poa* dominated, with few shrubs, whilst the S. has a *Casuarina* forest with a variety of smaller tree species, e.g. *Acacia*. *Poa* is present where the *Casuarina* is sparse and also in open areas which, however, are not always the most exposed to prevailing winds. In this instance, perhaps spray-bearing wind has been a factor in suppressing re-colonization by shrubs after burning on the north end, although there is no obvious evidence of fire now; rabbits are not known to have been present.)

Burrowing, by bird or rabbit, must assist in causing erosion. On Rabbit Island there are few burrows in the sand valley due to the birds' inability to maintain them in regions where there is little or no binding agent or soil consolidation. The process of burrowing also exposes the normally subterranean parts of the plant, covers up those parts above the surface to some extent and materially alters the conditions below soil level, by aerating, introduction of water and manuring (Gillham 1956). Caving in of burrows, whether by trampling or as the result of normal breakage, is of considerable importance in assisting further erosion in the area. There was no sign of rabbit warrens and I assume that the rabbits utilized bird burrows, or that their own burrows were indistinguishable in the rookeries.

The erosion across the summit has resulted in the removal of smaller sand particles and thus only large-grained sand is left. Sheet erosion has taken place and erosion gullies, caused by rain, are furthering the process. These gullies have become quite extensive and deep, particularly on the eastern side. In many places there are centres of erosion around what used to be mutton-bird burrows. In fact the whole of the now eroded area was at one stage occupied by birds, as is shown by the large number of burrows and bird remains which are present in the sand. The erosion gullies have contributed largely to the formation of outwashes, or spills, on the eastern side.

From consideration of the vegetation of Rabbit Island and the factors known to have influenced it, one can construct a possible sequence of interactions resulting in the present situation.

If the vegetation of the rookery can be considered as being relatively stable, in that there is an equilibrium between erosion and subsequent regeneration, then the following scheme could explain the formation of the Rabbit Island vegetation:

1. Vegetation stable within rookery.
2. Some small-scale erosion due to trampling and burrowing, wind and drought exert little influence.
3. Introduction of rabbits.
4. Reduction of vegetation and increase in dominance of some species due to selective feeding.
5. Erosion influence of wind and drought becoming more important.
6. Fires, caused deliberately or by accident, further reduce vegetation, rabbits prevent any large-scale regeneration.
7. Small sand-blows become larger as a result of soil properties.
8. Rookeries collapse, bare soil areas increase and finally sand-blow areas become extensive and coalesce.

Since the removal of the rabbits, by myxomatosis, has been almost complete it is thought that the use of poisoned bait might clear the island. This should allow regeneration of vegetation and assist the spread of species otherwise kept down by the selective pressure of the rabbits.

### Acknowledgements

I wish to thank the National Parks Authority for making this study possible and for the co-operation of their technical officer, Mr. D. Saunders. Thanks are also due to Miss H. Aston (National Herbarium), who identified the plant specimens, and Dr. D. F. Dorward for critical reading of the manuscript.

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### Appendix

List of plant species found on Rabbit Island during visit: plants recorded by Gillham (1961) recorded with an asterisk

#### BRYOPHYTES

- \* *Bryum campylothecium*. Common in rock crevices.
- Campylopus introflexus*. Frequent in rock crevices.

#### VASCULAR PLANTS, PTERIDOPHYTES

- \* *Pteridium esculentum*. Several communities in sand valley, probably associated with occasional fires.
- \* *Microsorium* (= *Polypodium*) *diversifolium*. One only found.
- Asplenium obtusatum*. A few clumps along W. side, just above splash zone.

#### PHANEROGRAMS

- \* *Poa poiformis*. Dominant species over most of the island.
- \* *Scirpus nodosus*. Occasional around coast.
- Juncus pallidus*. Few patches only found on W. side.
- Bulbine bulbosa*. Fairly common along S. end of island.
- \* *Dianella revoluta*. Occasional amongst *Poa*.
- \* *Cakile maritima*. Found along sand beach.
- \* *Stellaria media*. In several places along coast, particularly on cliffs on E. side.
- Urtica urens*. Abundant over all island, possibly an introduction since 1960.
- \* *Muehlenbeckia adpressa*. One stand only found.
- \* *Atriplex hastata*. Several clumps around coast.
- \* *Correa alba*. Occasional patches along W. and S. coasts.
- \* *Acacia longifolia* var. *sophorae*. Two stands only.
- Crassula helmsii* (= *recurva*). Very common over all island.

*Leptospermum laevigatum*. One occurrence only.

*Olearia axillaris*. Only one stand found.

\* *Disphyma australe*. Common along coast and on cliff faces.

\* *Carpobrotus rossii*. As above.

*Cotula australis*. Few found along coast.

\* *Senecio lautus*. Dominant species along edges of sand blow, found occasionally elsewhere.

\* *Carduus tenuifloris*. Dead plants and seedlings found in sand valley.

*Sonchus oleraceus*. A few specimens found along W. side.

\* *Lobelia alata*. Common in rock crevices near sea.

\* *Cyathodes acerosa*. One specimen only found.

Gillham found the following species which were not recorded during this visit: *Vulpia bromoides*, *Ammophila arenaria*, *Bulbine semibarbata*, *Calandrina calyptrata*, *Spergularia media*, *Crassula sieberiana*, *Cotula coronopifolia*; and the following were found on 1.3.66: *Atriplex cinerea*, *Tetragonia tetragonioides* and *Solanum laciniatum*.

Thus a total of 35 vascular plant species have been recorded from Rabbit Island.

### Explanation of Plate

#### PLATE 35

Aerial photograph looking N. along Rabbit Island. In the foreground the cover of *Poa* is shown with bare soil and *Poa* debris between the tussocks. The sand beach leads up to the valley and sand blow above. Note triangulation point in upper right corner. (Photograph by Dr. G. Ettershank.)







## AN EVALUATION OF LAND DEVELOPMENT, FLINDERS ISLAND

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### Abstract

The characteristics of the land development project of the Agricultural Bank of Tasmania are compared with those of pre-existing private grazing properties. The evaluation is in terms of methods of land development, capital value of properties, stocking rate, total carrying capacity, and type of farming as related to acreage, ownership and success in land improvement. It is concluded that the War Service Land Settlement Scheme has successfully developed a considerable area through high capitalization, and that transport to markets, whether of live animals or carcasses, is the urgent problem.

### Introduction

Flinders Island, the largest member of the Furneaux Group, lies in Bass Strait off the NE. coast of Tasmania; the coordinates  $148^{\circ}$  E. and  $40^{\circ}$  S. intersect near the centre of the island. Flinders Island is approximately forty miles from N. to S., fifteen to twenty miles from E. to W., and has an area of 513 square miles; it is 110 miles from Launceston by air, and 238 miles from Melbourne.

In 1947 a Joint Committee of both Tasmanian Houses of Parliament was appointed to examine communication facilities and the island's potential for war service land settlement. Land development was initiated by the Agricultural Bank of Tasmania in 1952; private development also occurred but was mainly confined to a small area in the S. and SE. The dune-lagoon complex of the east coast, and the poorly-drained S. and central plains either precluded grazing, or necessitated major clearing and drainage. The major problems associated with this rural land development have been discussed elsewhere (Pryor 1967).

### Status of Land Development

In general, the most highly developed properties (those fenced, cleared, and with improved pasture) are found on the W. coast between Emita and Loeceota, in a belt between Whitemark and Lady Barron, and in the occupied portions of the Agricultural Bank's Furneaux Estate through the centre of the island (Fig. 1). Private properties with native pasture are confined mainly to the northern third of the island; Agricultural Bank land of similar status, but undergoing further development, is found in the N., S., and E. margins of the Furneaux Estate. Alienated but unimproved properties are situated in the SE. between Logan Lagoon and Lady Barron, around Lughrata, and scattered in smaller pockets across the island.

Since the Second World War, there has been a 51.85 per cent increase in the number of rural holdings in the Flinders Municipality, with only two or three outside Flinders Island. Over the last ten years the increase has been 21.48 per cent, with 62 properties being established by the Agricultural Bank; there are a further 52 private properties.

Since 1945 there has been a considerable increase in the acreage of exotic pasture, and a limited expansion of native pasture. The unoccupied-undeveloped areas in 1964 may be accounted for in three ways: (i) the Strzelecki Scenic Reserve (SW.) and Lenna Forest Reserve (W. central) and their associated high-

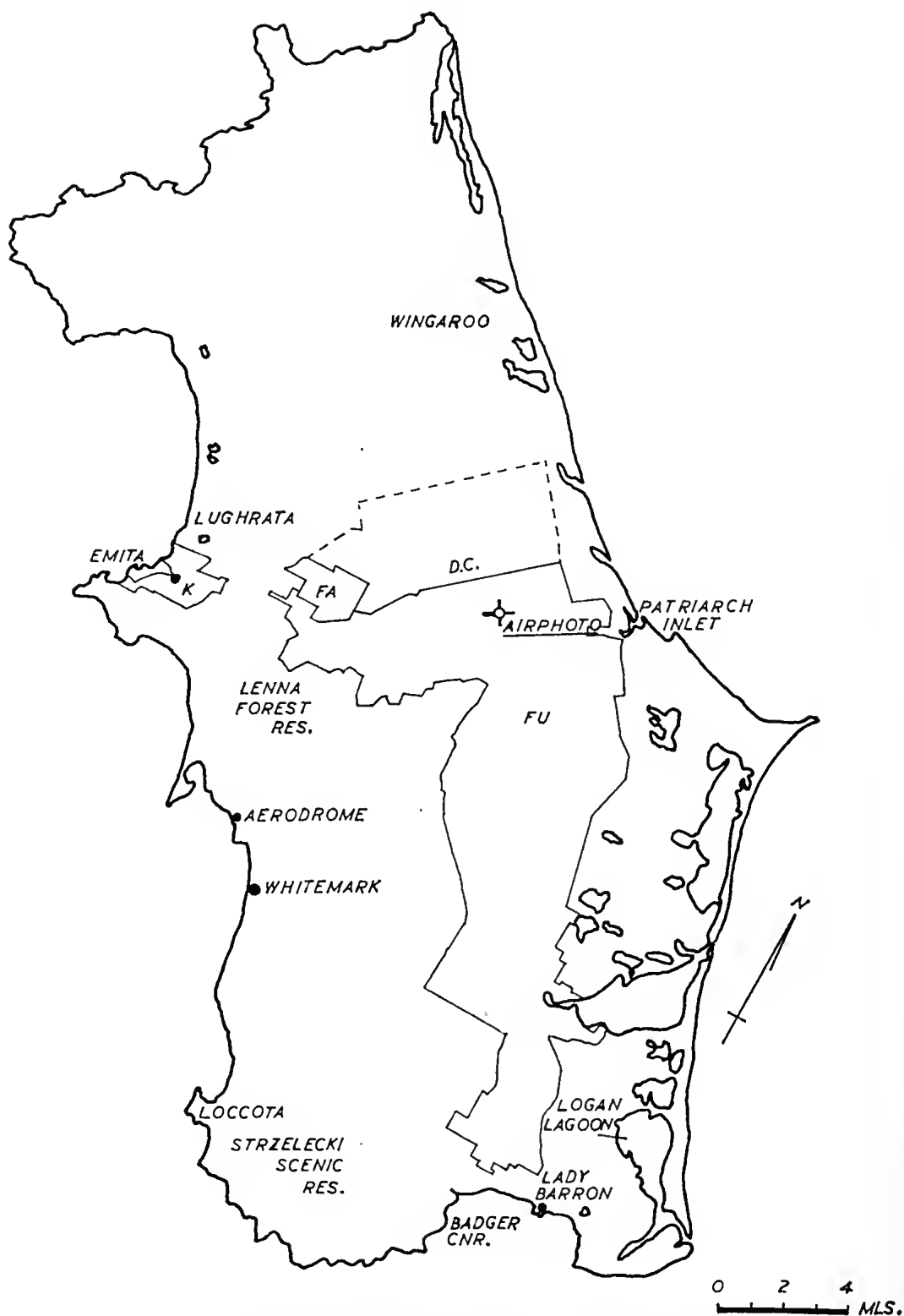


FIG. 1—Location map of Flinders Island. Key to Agricultural Bank Estates: K—Kentdale; FA—Fairhaven; FU—Furneaux; D.C.—Development continuing, no settlers; also estate in vicinity of Whitemark.

land masses; (ii) the Quoin soil association in the N., with highly leached soils over granite; and (iii) the dune-lagoon complex of the Nala-Lackrana-Memana soil associations on the E. coast. These three are at present legally inaccessible or cannot be developed economically, and apart from continued development immediately to the N. of the Furneaux Estate, little further expansion can be predicted.

Some indication of the sequence of land development adopted by the Agricultural Bank may be seen in the accompanying vertical aerial photograph (Pl. 36) and Fig. 2 located in the central N. of the Furneaux Estate, four miles from the E. coast. The area shown here is traversed by a 10 chain wide natural shelter belt, and by a major drain flowing E. to Patriarch Inlet. Two main roads run W.-E.: No. 2 road (to the N.), and No. 1 road (to the S., with access roads to four settlers' homes). Farm layout, some internal property divisions, siting of tanks and other features can be identified, and in summary, the history of land development is as follows:

1. **N. of "nature strip":** initial clearing 1958, ploughing 1959, seeding 1960, top dressing 1961 (when airphoto taken), liming and reseeded 1964; central portion is buffer block, remainder allocated as additional acreage to other properties; initial drainage channels unfilled and ungrassed at the time of airphoto; some natural shelter retained; area N. of No. 2 road as yet unallocated, and had not been sown in 1961.
2. **S. of "nature strip":** initial clearing 1952/3, ploughing 1954, seeding 1955, top dressing 1956, liming and reseeded 1957; redevelopment 1962/3 including CuCo superphosphate, with both potash and CuCo super S. of No. 1 road; minor drains now well grassed and some filled-in; some natural shelter retained; all properties now on permanent lease (1964).

An examination of official reports (Agricultural Bank of Tasmania, 1954-64) emphasizes both the high costs per ac. involved in land development, and the huge area actually 'reclaimed' (about 70,000 acres), and this confirms the conclusion that government finance—totalling some \$12m. to date—was the only possible medium; private settlers could not have borne the costs of clearing, draining, and pasture development, and yet some 62 private individuals have been placed on highly capitalized properties at very reasonable repayment terms, with many properties already achieving optimum turn-offs.

Three further aspects of land development will be outlined:

(a) **The average capital value of grazing properties** provides a useful index of land development. There are three main areas of low capital value per acre (up to \$16.00 per ac.) properties in the northern third of the island, the central W. coast, and the SE. In the N. and SE. many of the properties are unoccupied and have not been developed, and if fenced and cleared, do not have improved pasture; small properties and absenteeism are factors on the central W. coast.

The three areas of relatively high values (\$32.20 to \$92.00 per ac.) are the Kentdale-Fairhaven Estates, the Furneaux Estate, and private properties from the aerodrome S. and SE. to Loccota and the road N. from Lady Barron. On the one hand these include the larger Agricultural Bank and private grazing properties, and on the other hand small acreages with more intensive land use in the form of dairying. Within the Furneaux Estate there is a range from \$22 to \$74 per ac., reflecting the degree of development and sequence of occupation, the higher value properties in the N. having been developed first. These groups of high value properties are characterized by a relatively high degree of land development and

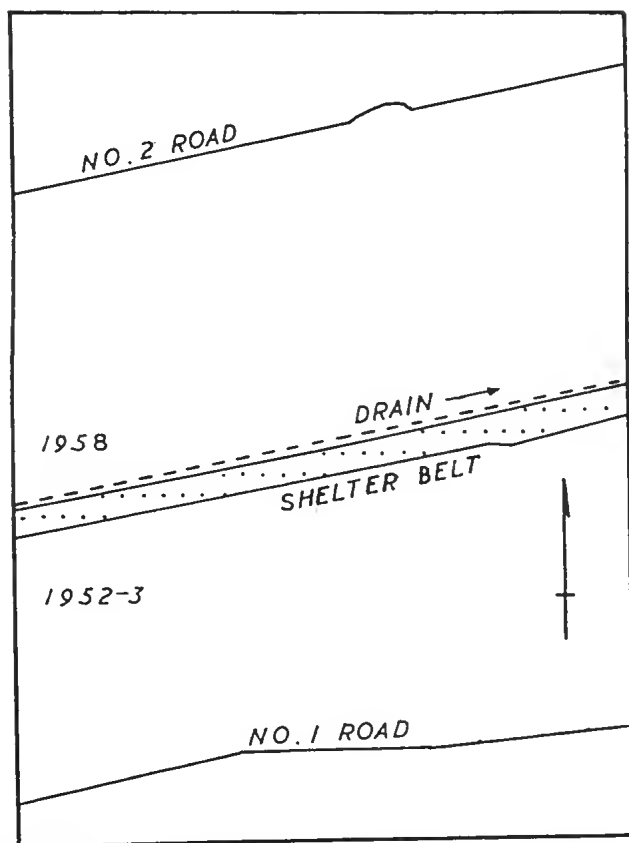


FIG. 2—Key diagram to airphoto, Plate 36; dates indicate commencement of clearing.  
For location, see Fig. 1.

pasture improvement. Two apparently nodal clusters (SE. of the aerodrome and Whitemark respectively) appear to be due to a combination of early development, favourable soils, and access to internal and external transport.

(b) **Stocking-rate** provides a second indirect index of land development. In terms of Fat Ewe Equivalents (Agricultural Bank of Tasmania, 1965) per ac. of total property acreage (as grazed acreage was not always known accurately on private properties), an outstanding feature is the low stocking rate on properties N. of Emita, and the comparatively higher rate S. of Whitemark, along the Lady Barron road, and E. from Emita through the Kentdale, Fairhaven and Furncaux Estates; there are, however, notable variations within and between properties. In general, the low score in the N. (average 0.49 FEE's/ac.) may be correlated with the absence of improved pasture, an earlier period of private settlement, and the highly calcareous soils of the Lughrata and Ranga soil associations. Agricultural Bank properties have a higher and more uniform rate (a majority have from 1.5 to 2.5 FEE's/ac.) because the total acreage of each block has been calculated to carry approximately 1200 FEE's, the estimated economic optimum; seven low scores here (0.5 to 1.49) indicate properties only recently occupied and in the

process of stocking-up, or recent sales of livestock with the farmers uncertain as to future purchases. The average for Flinders Island, based on the total acreage of all properties, is 1.55 FEE's/ac.; other averages are: all Bank properties 1.85; all private properties 1.36; and for all Bank properties, based on *acreage under pasture*, 2.29. Private holdings range from 0.23 to 3.56, and Bank blocks from 0.72 to 3.86 FEE's/ac. of total property acreage.

There is a complex cause-effect relationship between stocking-rate and capital value: a higher degree of land development as reflected in capital value makes possible a higher stocking-rate; and the higher the turn-off and subsequent income, the more finance available for redevelopment and continued pasture improvement.

(e) Fig. 3 below indicates the range of **current carrying capacity per property**, as distinct from stocking rate. Properties of private settlers exhibit the highest and lowest scores, from 20 to 8,450 FEE's per property (the 8,450 FEE's on a property of 3,283 acres could not be included in this figure). The clustering around 3-500 acres, and conversely the scattering above 1,000 acres, are important characteristics; dairy properties, or supplementary non-farm income, account in part for the former; a majority of all properties with less than 750 FEE's derive all, or some significant proportion of their income from dairying; this is consistent with the relatively high economic returns and grazing pressure per unit input in the dairy industry. The 'scatter' exhibited by private properties is primarily a reflection of land development, as already discussed. War Service Land Settlement Scheme (W.S.L.S.) properties range from 240 to 2,927 FEE's, with a concentration between 900 and 1,300. Inspection of Fig. 3 emphasizes (a) the essential differences, in acreage and carrying capacity, of the two types of properties; and (b) the fact that at the time of interview (January 1965) there was little direct conformity on W.S.L.S. properties to the recommended optimum carrying capacity.

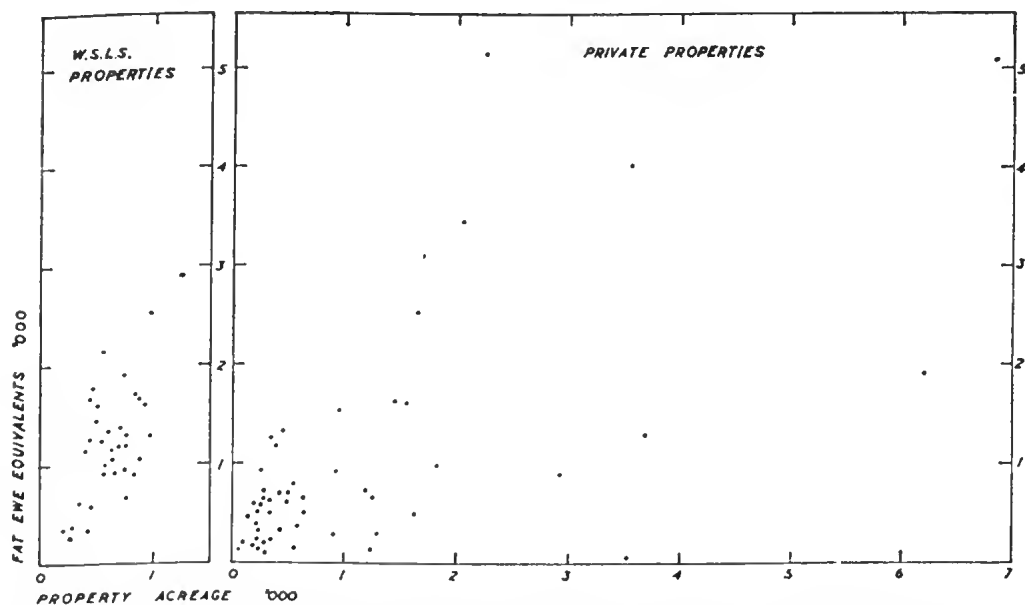


FIG. 3—Carrying capacity in fat ewe equivalents by property acreage, for private and War Service Land Settlement Scheme properties. (One head of beef or dairy cattle represents five FEE's.)

### Current Types of Farming

The Furneaux Group has not featured in studies of the agricultural geography of Tasmania; Scott, for example, explicitly excludes all Bass Strait islands 'owing to the need for a compact laboratory', but in a 1961 paper extended his 'Minor Grazing Areas' category to include Flinders Island 'which was not included in the farm survey, (but) may be regarded both physically and agriculturally as a detached portion of the Far Northeast' (Scott 1961). This is an adequate generalization at this level but detailed studies reveal greater variety.

In 1946 there were 108 'rural holdings' in the municipality, and 164 in 1963-4, an increase of 51.9 per cent; during the same period the number of properties grazing cattle increased 43.2 per cent, and sheep 108.8 per cent (Commonwealth Bureau of Census and Statistics, 1945-64). The map (Fig. 4) indicates major areas of dairying, beef or sheep grazing, and combinations of these three; the type-of-farming category is dependent upon the source of  $\frac{2}{3}$  or more of total income for each property.

Sheep properties are outstanding on the Agricultural Bank's Furneaux Estate through the centre of the island, and others are scattered along the road between Whitemark and Lady Barron in the S. and SW. In general this coincides with improved pasture, higher carrying capacity, a rainfall of 30-31 inches per annum, and the Wingaroo, Whitemark, Metta, Lenna and some Quoin soil associations. Dairying is the dominant income source on ten properties scattered between the Agricultural Bank's Kentdale and Fairhaven Estates (central W.), Locootia (SW.), and Badger Corner (SE.); these are on improved pasture of moderate carrying capacity, with a wide variety of soil types, and rainfall from 28-31 inches. There are three beef properties in the NW., and three in the SW. on Lady Barron Road. The beef-sheep combination is common both in the NW., often on unimproved pasture of low carrying capacity, and in the central S. on improved pasture with a moderate to high stocking rate. Properties between Whitemark and Lady Barron exhibit greatest heterogeneity in type of grazing, and the Furneaux Estate, and to a less extent the Lughratta area, relative homogeneity.

Table 1 shows the type of farming, property acreage, and relative sizes of herds or flocks, for the 89 properties (from a total of 114 major grazing properties) for which this information was obtained by interview; it should be noted that one

TABLE 1  
*Classification of livestock numbers by property acreage*

Property Acreage	Sheep				Beef Cattle				Dairy Cattle			
	1-399	400-799	800-1199	1200+	1-49	50-149	150-449	450+	1-9	10-29	30-89	90+
1-99	1	-	-	-	-	-	-	-	1	1	-	-
100-499	10	5	2	3	11	10	1	-	5	7	10	1
500-999	3	5	13	10	17	8	1	-	11	2	3	-
1000-2999	2	3	-	4	3	4	3	1	3	-	-	1
3000-4999	1	1	-	2	-	1	-	2	2	-	-	-
5000+	-	-	1	1	-	-	1	1	2	-	-	-
Total	17	14	16	20	31	23	6	4	24	10	13	2

farm grazing sheep, beef and dairy cattle, would appear three times in the table opposite the appropriate acreage. About 43 per cent of the properties have an acreage between 500-999, and about 36 per cent between 100-499 ac., the former being strongly weighted by Agricultural Bank properties which average 615 ac.

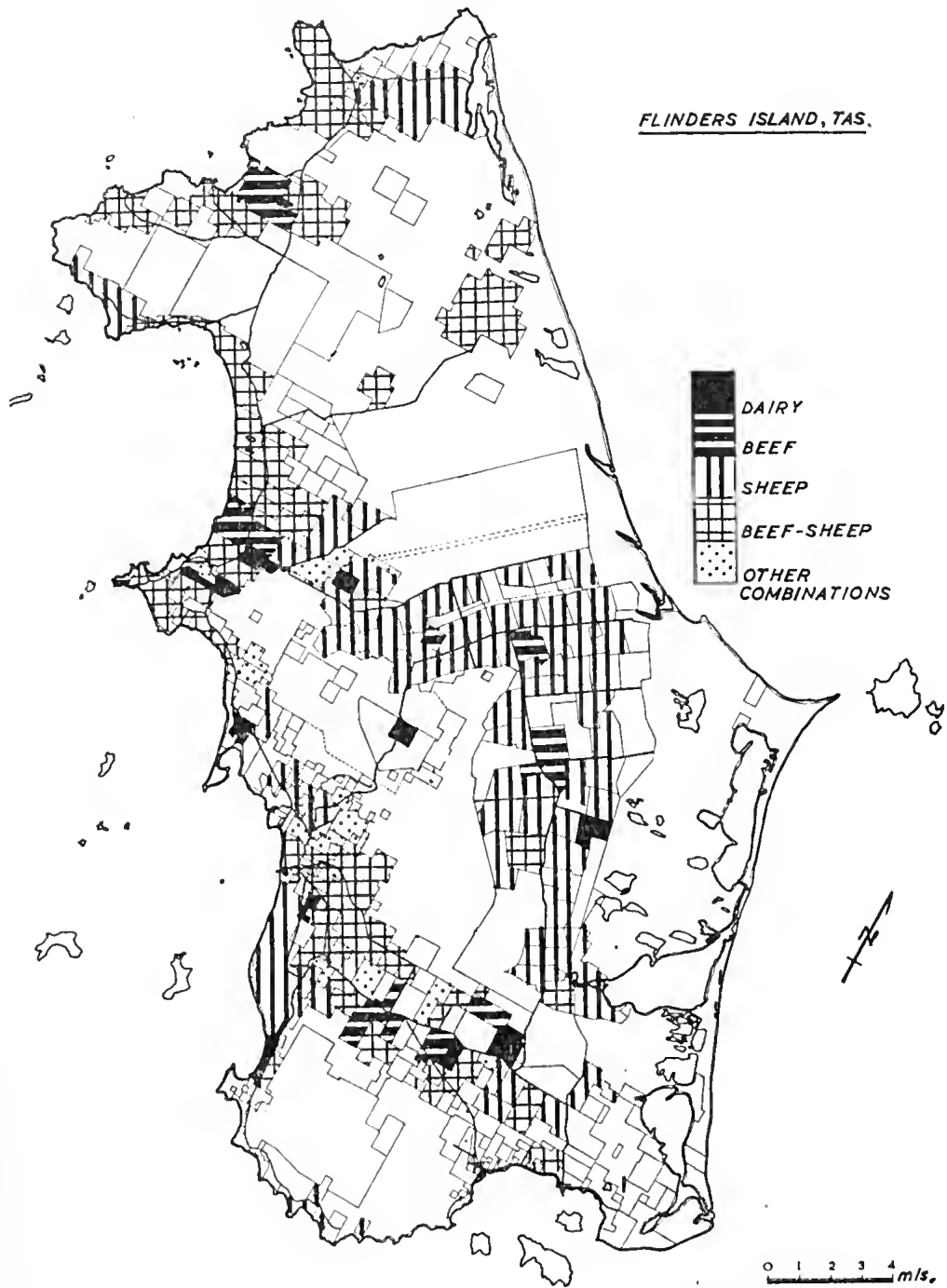


FIG. 4—Types of farming, 1965, based on the source of two-thirds or more income by properties.

(62 Bank properties range from 218-1,095 ac.). There is a fair diversity of flock size; beef herds tend to be less than 100; the average dairy herd size is 48, and several properties run a small number of house cows.

The disparity between the two groups of holdings by type of farming is emphasized. Thus, from Table 2, 56 per cent of holdings derive their major income from sheep (wool and/or mutton), 46 per cent of the total being Agricultural Bank properties; in the latter case, all except 10 properties also run beef cattle,

TABLE 2  
*Type of farming as a % of properties grazed*

	Dairy	Beef	Sheep	Beef-Sheep	Other combinations
Private settlers	15.8%	7.0	10.5	10.5	1.8
Bank settlers	5.3%	—	45.6	1.8	1.8
Total, 114	24	8	64	14	4

because of the general Bank policy of diversification of income. While there are 24 properties which derive their major income from butter-fat production, a total of 38 make regular deliveries to the Island's butter factory, 14 of these latter having an alternative major income source.

Of the 34 sheep graziers who provided the information, 29 (85 per cent) received at least ½ of their total income from wool sales, fat lambs being the major source for only 5. This is in part a matter of supply and demand, as the average annual prices for fat lambs have shown a general tendency to decline throughout Australia from the peak levels of 1954-5 and 1955-6. Marketing costs are perhaps more significant in the case of Flinders Island, particularly those involved in transferring livestock to either Victoria or Tasmania; delay due to bad weather and the danger of damage in transit are far less serious hazards in the shipping of wool than for livestock or carcasses, and the storage and handling costs are considerably lower.

### Conclusion

Despite the varied and spasmodic history of settlement and land development on Flinders Island, activity by the Agricultural Bank of Tasmania under the War Service Land Settlement Scheme has since 1952 successfully placed over sixty settlers on land which could not readily be developed by private resources; already many of these grazing properties are achieving predicted optimum turn-offs, despite considerable variation (positive and negative) from the recommended carrying capacity; the turn-off expected from the 1,200 FEE carrying capacity is of the order of 600 fat lambs or hoggets, 140 culled ewes and 25 beef cattle. At the lower end of the scale, variation in the number of livestock actually held is a function of incomplete development or redevelopment, or a recent large sale which depressed livestock numbers at the time of field interviews; on the positive side, a relatively high stocking rate and/or carrying capacity reflects well advanced land development and management efficiency. In other instances, overstocking is the problem; this may, in the future, depress carrying capacity and turn-off numbers, and cause a decline in animal health due to pasture and soil depletion. A high rate



reflects also, in a small number of cases, the use of non-bank pasture for the purpose of building up (and occasionally concealing) livestock numbers.

Less amenable to measurement is the benefit to private settlers of the findings of Dimmock's soils survey (Dimmock 1957), and subsequent soil, fertilizer and pasture research, with co-operation between various State and Commonwealth Government departments. This development in the 'private sector', together with the Government's injection of considerable financial and personnel resources into large-scale land development has already had its impact. The economic position of the island has been changed from one of isolation and stagnation, indeed of economic decline, to a point where the urgent problem is not one of potential improvement in quality or quantity, but the mechanical difficulty of disposing of the livestock produced. Development has been artificially stimulated, and the result requires urgent attention: transport must be provided to Tasmanian markets, and increased to Victorian markets. A second and inseparable problem is whether to transport live animals, or carcasses killed and frozen on the Island.

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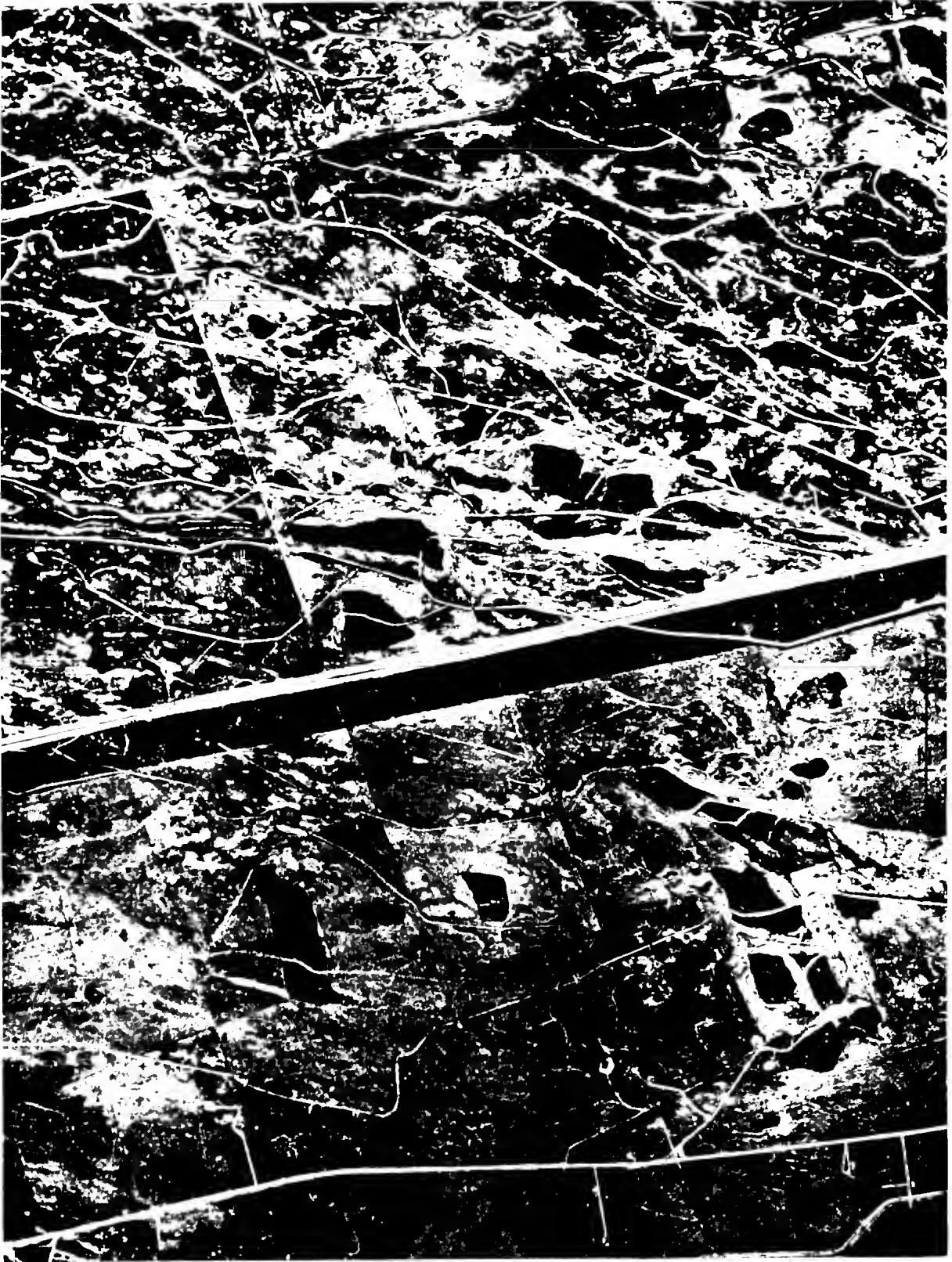
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### Explanation of Plate

#### PLATE 36

A portion of the War Service Land Settlement Scheme Furneaux Estate; see text for explanation. (Scale: 1 inch to 1670 feet; Lands and Surveys Department, Hobart, Run 5, T362-77, 1961.)







## THE VERTEBRATE FAUNA OF THE BASS STRAIT ISLANDS:

## 2. THE REPTILIA OF FLINDERS AND KING ISLANDS

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## Introduction

Main (1961) drew attention to the value of continental islands for deducing changes in animal distributions since the last glacial period, when the sea level was much lower than at present, and the climate colder. Using a similar approach, Littlejohn & Martin (1965) reconstructed the probable post-glacial history of SE. Australia and analysed the amphibian fauna of Flinders Is., King Is., Tasmania and S. Victoria in the light of this reconstruction. They point out that during the last glacial period an extensive landbridge (the Bassian isthmus), incorporating all the present Bass Strait islands, existed between S. Victoria and Tasmania. According to Littlejohn and Martin the probable sequence of the post-glacial submergence of this landbridge was as follows:

16,000	years	before	present:	Eustatic rise in sea level commenced.
14,000	"	"	"	Cape Otway to King Is. link broken.
12,000	"	"	"	Wilsons Promontory to Flinders Is. link broken.
11,000	"	"	"	King Is. to Tasmania link broken.
10,000	"	"	"	Flinders Is. to Tasmania link broken.
6,000	"	"	"	Present coastline attained.

The present paper lists accurate reptile species records for Flinders Is. and King Is. Most of these records are from specimens collected on trips to the islands by members of the University of Melbourne Zoology Department (MUZD); however, three species records are based on specimens in the National Museum of Victoria and one other on literature records alone. Trips were made to Flinders Is. in October 1962 and February 1964, and to King Is. in November 1963 and March 1964.

Species records for S. Victoria and Tasmania are also provided for comparative purposes. The S. Victorian list is based on specimens in the MUZD collection. S. Victoria is taken as the area S. of the Great Dividing Range and, for discussion purposes, has been divided into E. and W. zones by a line passing N.-S. through Melbourne. A Tasmanian species list was compiled from specimens in the MUZD and from literature records, and this basic list was modified by Mr. R. N. Green, Zoologist, Queen Victoria Museum, Launceston and Mr. B. C. Mollison, Inland Fisheries Commission, Hobart, to give the final list. Three species (*Amphibolurus adalaidensis*, *A. muricatus* and *Tiliqua scincoides*) recorded from Tasmania in the most recent account of Tasmanian lizards (Hewer 1948) were deleted by Green and Mollison.

Following the ideas of Main (1961) and Littlejohn & Martin (1965) the data mentioned above can be discussed in three main ways:

1. The nature of the E. and W. sides of the Bassian landbridge can be suggested by comparing the reptile faunas of Flinders Is. and King Is.

2. The present relationships, and hence origin, of the Flinders Is. and King Is. reptile faunas can be suggested by comparison to the reptile faunas of Tasmania and S. Victoria.
3. The occurrence of post-glacial intrusive species in S. Victoria can be inferred by comparing the reptile fauna of Tasmania (and the Bass Strait islands) with that of S. Victoria.

Following the methods of Rawlinson (1966), the zoogeographic position of Tasmania can also be determined. This is achieved by comparing the reptile fauna of Tasmania with that of Gippsland (SE. Victoria), a typical Bassian area (*sensu* Rawlinson 1966).

Littlejohn & Martin (1965) have given general descriptions of Flinders Is. and King Is., discussing physiography, climate and vegetation in detail. They also provide maps of the islands which show all localities mentioned in this article.

### Reptile Fauna

As with the amphibians of this area (Littlejohn & Martin 1965), no cryptic species were found on either island. Specimens from the islands were compared to specimens of the same species from S. Victoria and Tasmania before positive identifications were made. Two of the three snake species, *Denisonia superba* and *Notechis ater*, belong to species complexes in SE. Australia and accordingly comparison was made to the relevant Victorian and Tasmanian populations. None of the lizard species found on the islands is known to belong to a species complex in SE. Australia.

In the following locality records, data for each species are presented under three sub-headings: 'Specimens examined', which includes the localities of all specimens collected on the islands and in five instances, localities of specimens in the National Museum of Victoria; 'Specimens observed', which includes the localities of all reptiles seen but not collected, the main source of such data being road casualties which are designated by 'DOR' (dead on road); and 'Literature records', which includes all literature records which are considered to be accurate. References to small islands adjacent to Flinders or King Islands (e.g. Chappell Is., Furneaux Group; New Year Is., off King Is.) have been listed with localities for the large island. Literature records which are considered to be doubtful are listed with a brief explanation after the conclusion of accurate data for each island. Non-specific references (e.g. Bass Strait islands) have been listed for completeness.

## I. FLINDERS ISLAND

### AGAMIDAE

#### *Amphibolurus diemensis* (Gray)

SPECIMENS EXAMINED: Camerons Inlet, 4 miles E. of The Dutchman, 1 juv.; Walanippi, 7 miles SE. of Whitemark, 1.

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Furneaux Group (Frost 1893 as *Amphibolurus angulifera*); Flinders Is. (Zeitz 1914 as *Amphibolurus angulifera*).

### SCINCIDAE

#### *Egernia whitei* (Lacépède)

SPECIMENS EXAMINED: South Branch Pats River, 2 miles N. of Whitemark, 1; The Dutchman, 1; Reids Peak, 4½ miles SE. of Whitemark, 1; Mt. Barclay,

5 miles SE. of Whitemark, 4; Walanippi, 7 miles SE. of Whitemark, 1; Mt. Strzelecki, 2; Loccota, 11; Badger Corner, near Loccota, 1.

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Furneaux Group (Frost 1894); Mt. Strzelecki, Flinders Is. (MacKay 1955).

***Leiolopisma entrecasteauxi* (Duméril & Bibron)**

SPECIMENS EXAMINED: The Dutchman, 1; Loccota, 1.

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Fisher Is., Furneaux Group (MacKay 1955).

***Leiolopisma metallicum* (O'Shaughnessy)**

SPECIMENS EXAMINED: Mcmana, 1; 8 miles NNW. of Whitemark, 10; Nelson Lagoon, 7 miles N. of The Dutchman, 1; North Branch Pats River, 2½ miles N. of Whitemark, 1; South Branch Pats River, 2 miles N. of Whitemark, 1; The Dutchman, 10; 1 mile E. of The Dutchman, 2; Camerons Inlet, 4 miles E. of The Dutchman, 2; Rcids Peak, 4½ miles SE. of Whitemark, 1; Walanippi, 7 miles SE. of Whitemark, 10; Loccota, 2; Fisher Is. off Lady Barron, 2.

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Furneaux Group (Frost 1894).

***Leiolopisma ocellatum* (Gray)**

SPECIMENS EXAMINED: The Dutchman, 28; Mt. Barclay, 5 miles SE. of Whitemark, 7; Mt. Strzelecki, 1; Trousers Point, ½ mile SW. of Loccota, 1.

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Furneaux Group (Frost 1894); Mt. Strzelecki, Flinders Is. (MacKay 1955).

***Leiolopisma pretiosum* (O'Shaughnessy)**

SPECIMENS EXAMINED: Flinders Is., 1 (Specimen D911, National Museum).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Nil.

***Leiolopisma trilineatum* (Gray)**

SPECIMENS EXAMINED: Pats River, 2 miles N. of Whitemark, 1; The Dutchman, 2; Camerons Inlet, 4 miles E. of The Dutchman, 9 eggs (hatched 8.III.64); Mt. Barclay, 5 miles SE. of Whitemark, 2; Loccota, 4.

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Little Dog, Big Dog, Babel and Flinders Islands, Furneaux Group (MacKay 1955).

***Rhodona bougainvilli* (Gray)**

SPECIMENS EXAMINED: Nil.

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Babel Is., Furneaux Group (MacKay 1955).

***Tiliqua nigrolutea* (Quoy & Gaimard)**

SPECIMENS EXAMINED: Trousers Point, ½ mile SW. of Loccota, 1.

SPECIMENS OBSERVED: Whitemark, 1 DOR; The Dutchman, 1 DOR; 4 miles S. of The Dutchman, 1 DOR.

LITERATURE RECORDS: Babel Is., Furneaux Group (MacKay 1955); Flinders Is. (Mitchell 1950); Flinders Is. (Zeitz 1914).

TABLE 1

Summary of reptilian distribution in the Bass Strait area

Species	SE. Victoria	SW. Victoria	Flinders Island	King Island	Tasmania
CHELYIDAE					
<i>Chelodina longicollis</i>	+	+	—	—	—
AGAMIDAE					
<i>Amphibolurus barbatus</i>	—	+	—	—	—
<i>A. diemensis</i>	+	—	+	—	+
<i>A. muricatus</i>	+	+	—	—	—
<i>Physignathus lesueuri</i>	+	—	—	—	—
<i>Tympanocryptis lineata</i>	—	+	—	—	—
GEKKONIDAE					
<i>Phyllodactylus marmoratus</i>	—	+	—	—	—
PYGOPODIDAE					
<i>Delma impar</i>	—	+	—	—	—
SCINCIDAE					
<i>Ablepharus lineocellatus</i>	—	+	—	—	—
<i>Egernia cunninghami</i>	+	+	—	—	—
<i>E. luctuosa</i>	—	+	—	—	—
<i>E. saxatilis intermedia</i>	+	+	—	—	—
<i>E. whitei</i>	+	+	+	+	+
<i>Emoia spenceri</i>	+	—	—	—	—
<i>Hemiergis decresiensis</i>	+	+	—	—	—
<i>Leiopisma delicata</i>	+	—	—	—	—
<i>L. entrecasteauxi</i>	+	+	+	+	+
<i>L. guichenoti</i>	+	+	—	—	—
<i>L. metallicum</i>	+	+	+	+	+
<i>L. mustelinum</i>	+	—	—	—	—
<i>L. ocellatum</i>	—	—	+	—	+
<i>L. pretiosum</i>	—	—	+	—	+
<i>L. trilineatum</i>	+	+	+	+	+
<i>L. weeksae</i>	+	+	—	—	—
<i>Rhondona bougainvilli</i>	+	+	+	—	+
<i>Siaphos maccoyi</i>	+	+	—	—	—
<i>Sphenomorphus lesueuri</i>	—	+	—	—	—
<i>S. quoyi tympanum</i>	+	+	—	—	—
<i>S. sp. nov.</i>	+	—	—	—	—
<i>Tiliqua casuarinae</i>	+	—	—	—	—
<i>T. nigrolutea</i>	+	+	+	+	+
<i>T. rugosa</i>	—	+	—	—	—
<i>T. scincoides</i>	+	+	—	—	—
VARANIDAE					
<i>Varanus varius</i>	+	—	—	—	—
ELAPIDAE					
<i>Demansia textilis</i>	+	+	—	—	—
<i>Denisonia coronoides</i>	+	+	+	+	+
<i>D. flagellum</i>	—	+	—	—	—
<i>D. nigrescens</i>	+	—	—	—	—
<i>D. superba</i>	+	+	+	+	+
<i>D. sp. nov.</i>	+	—	—	—	—
<i>Notechis ater</i>	—	—	+	+	—
<i>N. scutatus</i>	+	+	—	—	+
<i>Pseudechis porphyriacus</i>	+	+	—	—	—
TOTALS	31	30	12	8	14



## ELAPIDAE

**Denisonia coronoides** (Günther)

SPECIMENS EXAMINED: The Dutchman, 1; Walanippi, 7 miles SE. of Whitemark, 2.

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Babel, Fisher and Flinders Islands, Furneaux Group (MacKay 1955).

**Denisonia superba** (Günther)

SPECIMENS EXAMINED: Nelson Lagoon, 7 miles N. of The Dutchman, 1; 5 miles SE. of Whitemark, 1; 3½ miles N. of Loceota, 5.

SPECIMENS OBSERVED: 2 miles N. of Whitemark, 1 DOR; 2 miles N. of Loceota, 1 DOR; Lady Barron, 1 DOR.

LITERATURE RECORDS: Fisher, Big Dog, Little Green and Flinders Islands, Furneaux Group (MacKay 1955); Great Dog and Flinders Islands, Furneaux Group (Worrell 1963a); Flinders Is. (Zeitz 1914).

**Notechis ater** (Krefft)

SPECIMENS EXAMINED: Chappell Is., Furneaux Group, 1 (Specimen D8674 National Museum).

SPECIMENS OBSERVED: 3 miles S. of The Dutchman, 1 DOR.

LITERATURE RECORDS: Cat Is., Furneaux Group (Cashion 1959 as *Notechis scutatus niger*); Chappell Is., Furneaux Group (Kellaway & Thomson 1932 as *Notechis scutatus niger*); Chappell Is., Furneaux Group (Kingham 1956 as *Notechis scutatus niger*); Babel Is., Furneaux Group (LeSouef 1902 as *Hoplocephalus curtus*); Chappell, Cat, Babel, Forsyth and Flinders Islands, Furneaux Group (MacKay 1955 as *Notechis scutatus*); Chappell Is., Furneaux Group (Worrell 1958 as 'Black Tiger Snake'); Babel and Chappell Islands, Furneaux Group (Worrell 1963a as *Notechis* sp.); Chappell Is., Furneaux Group (Worrell 1963b as *Notechis ater serventyi*); Babel and Chappell Islands, Furneaux Group (Worrell 1963c as *Notechis ater serventyi*); Flinders Is., Furneaux Group (Zeitz 1914 as *Notechis scutatus*).

## DOUBTFUL LITERATURE RECORDS FOR FLINDERS ISLAND

## ELAPIDAE

**Demansia textilis** (Duméril & Bibron)

RECORDS: Furneaux Group (Frost 1894 as *Diemenia superciliosa*).

Frost was not a member of the expedition to the Furneaux Group, and his report of five lines is not very specific. He makes no mention of the three common species of snakes (*Denisonia coronoides*, *D. superba* and *Notechis ater*); thus his record of *D. textilis* must be regarded as doubtful and probably attributable to *D. superba*.

## II. KING ISLAND

## SCINCIDAE

**Egernia whitei** (Lacépède)

SPECIMENS EXAMINED: Naracoopa, 3 (Specimens D1245, D2626-7 National Museum).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: King Is. (Lucas & Frost 1893).

TABLE 2

*Reptilian distribution patterns in the Bass Strait area*

Possible distribution patterns	Number of reptile species showing pattern
Victoria only	29
Victoria and Flinders Island	—
Victoria and King Island	—
Victoria and Tasmania	2
Victoria, Flinders and King Islands	—
Victoria, Flinders and King Islands and Tasmania	7
Victoria, Flinders Island and Tasmania	2
Victoria, King Island and Tasmania	—
Flinders and King Islands and Tasmania	1*
Flinders and King Islands	—
Flinders Island and Tasmania	2
King Island and Tasmania	—
Flinders Island only	—
King Island only	—
Tasmania only	—
TOTAL	43

\* This species, *Notechis ater*, does not occur in southern Victoria; however it does occur on the Australian mainland in South Australia (Worrell 1963b) and Western Australia (Rawlinson MS.).

***Leiopisma entrecasteauxi* (Duméril & Bibron)**

SPECIMENS EXAMINED: Cape Wickham, 5 miles NNW. of Egg Lagoon, 2; Parnanna, 3 miles W. of Naracoopa, 1; Naracoopa, 1; Seal Rocks, 4 miles SW. of Pearshape, 2.

SPECIMENS OBSERVED: Nil.

LITERATURE RECORD: Nil.

***Leiopisma metallicum* (O'Shaughnessy)**

SPECIMENS EXAMINED: 6 miles NW. of Currie, 1; Parnanna, 3 miles W. of Naracoopa, 11; Yarra Creek, 2.

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Nil.

***Leiopisma trilineatum* (Gray)**

SPECIMENS EXAMINED: King Is., 2 (Specimens D2621 and D2624 National Museum).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Nil.

***Tiliqua nigrolutea* (Quoy & Gaimard)**

SPECIMENS EXAMINED: 2½ miles E. of East Wickham, 1; Pegarah, 1; Pearshape, 1; Grassy, 1.

SPECIMENS OBSERVED: 1 mile N. of Egg Lagoon, 1 DOR; East Wickham, 1 DOR; Currie, 1 DOR; 6 miles E. of Currie, 1 DOR; 4 miles SE. of Currie, 2 DOR; Grassy Creek, 2 miles N. of Grassy, 1 DOR; Pearshape, 1 DOR; Grassy, 1 DOR; Seal Rocks, 4 miles SW. of Pearshape, 1 DOR; Surprise Bay, 1 DOR.

LITERATURE RECORDS: King Is. (LeSouef 1888 as *Cyclodus nigroluteus*); King Is. (Spencer 1888 as *Cyclodus gigantea*).

TABLE 3  
Comparison of the Tasmanian and Gippsland reptile faunas

Family	Number of species in Tasmania	Number of species in Gippsland	Number of shared species
<b>CHELONIA</b>			
Chelyidae	—	1	—
<b>LACERTILIA</b>			
Agamidae	1	3	1
Scincidae	10	19	8
Varanidae	—	1	—
<b>OPHIDIA</b>			
Elapidae	3	7	2
TOTALS	14	31	11

## ELAPIDAE

**Denisonia coronoides** (Günther)

SPECIMENS EXAMINED: Nil.

SPECIMENS OBSERVED: Pegarah, 1 DOR; Parenna, 3 miles W. of Naracoopa, 1 DOR.

LITERATURE RECORD: King Is. (LeSouef 1888 as *Hoplocephalus coronoides*).**Denisonia superba** (Günther)

SPECIMENS EXAMINED: 6½ miles E. of Loorana, 1; Parenna, 3 miles W. of Naracoopa, 3; Naracoopa, 1 juv.

SPECIMENS OBSERVED: 4 miles E. of Egg Lagoon, 1 DOR; East Wickham, 1 DOR.

LITERATURE RECORDS: King Is. LeSouef 1888 as *Hoplocephalus superbus*; King Is. (Worrell 1963a).**Notechis ater** (Krefft)

SPECIMENS EXAMINED: New Year Is. off King Is., 8 (Specimens D8540-1 and D9000-5 National Museum); Christmas Is., off King Is., 1 (Specimen D9006 National Museum).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: New Year Is. and Seal Rocks, King Is. (LeSouef 1888 as *Hoplocephalus curtus*); Christmas, New Year and King Islands (Worrell 1963a as *Notechis* sp.); Christmas, New Year and King Islands (Worrell 1963b as *Notechis ater humphreysi*); Christmas, New Year and King Islands (Worrell 1963c as *Notechis ater humphreysi*).

## DOUBTFUL LITERATURE RECORDS FOR KING ISLAND

## SCINCIDAE

**Tiliqua scincoides** (Shaw)RECORDS: King Is. (Spencer 1888 as *Cyclodus gigantea*); King Is. (Lucas & Frost 1893).Spencer refers to the large bluetongues and smaller skinks as being abundant. He mentions only *Cyclodus gigantea* in his report. As LeSouef in the same paper

records only *Cyclodus nigroluteus* (= *T. nigrolutea*) from King Is., it is clear that Spencer used the wrong name. Lucas & Frost almost certainly copied Spencer's mistake.

#### ELAPIDAE

##### *Demansia textilis* (Duméril & Bibron)

RECORDS: Ettrick River, King Is. (LeSouef 1888 as *Diemenia superciliosa*).

In his account of the Reptilia of King Is., LeSouef emphasizes the colour variations of the island snake species and in fact seems to have used body colour as a diagnostic feature. For example he appears to consider transverse banding a characteristic of the tiger snake (*N. ater*). LeSouef records island specimens of the copperhead (*D. superba*) as dark in colour, one or two being 'mistaken at first for black snakes' (*Pseudechis porphyriacus*). The present author found that island populations of *D. superba* included the common dark morph mentioned by LeSouef and also light brown and reddish brown variants. It seems probable that LeSouef's *D. superciliosa* was a light brown specimen of *D. superba*. Similarly the 'red water snake' he mentions was probably a reddish variant of *D. superba*.

#### NON-SPECIFIC REFERENCES

Hewer 1948:

*Leiopisma metallicum*; Tasmania and adjacent islands.

*Tiliqua casuarinae*; Tasmania and Tasmanian islands.

LeSouef 1888:

*Hinulia* (?) two spp.; King Is. (Probably *Leiopisma* spp., author).

McPhee 1962:

*Tiliqua nigrolutea*; Bass Strait islands.

Worrell 1963a:

*Leiopisma ocellatum*; Tasmania and adjacent islands.

*Rhodona bougainvilli*; Tasmania and Bass Strait islands.

*Tiliqua nigrolutea*; Tasmania and Bass Strait islands.

#### Discussion

As a result of this survey 4 species of reptiles are recorded from the Bass Strait islands for the first time: *Leiopisma pretiosum* on Flinders Is. and *Leiopisma entrecasteauxi*, *L. metallicum* and *L. trilineatum* on King Is. On the other hand 3 earlier species records have been shown to be of doubtful accuracy. *Demansia textilis* on Flinders Is. and *Tiliqua scincoides* and *Demansia textilis* on King Is. This leaves Flinders Is. with 12 definite species records and King Is. with 8 definite species records.

Altogether 43 species of reptiles have been considered. Their distributions in S. Victoria, Flinders Is., King Is. and Tasmania are summarized in Table 1. Table 2 shows that of 15 possible distribution patterns, only 6 actually occur. As mentioned in the introduction, these data can be discussed along four main lines to reach four separate, but related, conclusions. This is done under four headings:

1. Comparison of the reptile faunas of Flinders and King Islands.
2. Comparison of the reptile faunas of Flinders and King Islands with those of Tasmania and S. Victoria.
3. Comparison of the reptile faunas of Tasmania and S. Victoria.
4. Determination of the zoogeographic position of Tasmania.

Before starting the discussion proper, some points which arose during the collection of data should be clarified. Firstly, *Egernia luctuosa* is recorded from Victoria for the first time in Table 1. Mitchell (1950) in his revision of the genera *Egernia* and *Tiliqua* transferred *luctuosa* from the former to the latter genus. However, the present author has found that using Mitchell's definitions of these genera (based on head scalation, palatine bones and dentition) the previous arrangement is correct and accordingly the name *Egernia luctuosa* has been used in Table 1. Secondly, three other taxa used need further comment. Two are not Bass Strait island species and need only brief explanation; these are *Sphenormorphus* sp. nov. and *Denisonia* sp. nov. (see Table 1). Both taxa have apparently reached species status (Rawlinson, unpublished), the former being a member of the *Sphenormorphus quoyi* complex and the latter a member of the *Denisonia superba* complex, and both are apparently undescribed. The third taxon needing further comment is *Notechis ater*. Worrell (1963b) and the author (MS.) both consider that in E. Australia *Notechis scutatus* is restricted to the Murray-Darling river system, SE. Queensland, E. New South Wales, Victoria, SE. South Australia and E. Kangaroo Is. Worrell (*op. cit.*) regards *N. ater* as occurring in Tasmania, the Bass Strait islands, W. Kangaroo Is., all other South Australian offshore islands, the Yorke and Eyre Peninsulas and Flinders Ranges, South Australia. Worrell's usage of *N. ater* is here followed; however it is not considered that there are adequate grounds for recognition of subspecies (see Worrell 1963b and c in 'Literature records' for Flinders and King Islands). In addition the author (MS.) considers the Western Australian form to be referable to *N. ater*. Rawlinson (1966) has previously recorded Western Australian *Notechis* specimens as *N. scutatus*. A reassessment of data on all *Notechis* populations for the present paper resulted in this subsequent change.

### 1. Comparison of the reptile faunas of Flinders and King Islands

Eight species of reptiles are known to occur on King Is. and all are shared with Flinders Is. and Tasmania (Tables 1 and 2). In addition, all reptile species occurring on King Is. have fairly extensive distributions on the Australian mainland: four species, *Egernia whitei*, *Leiopisma metallicum*, *L. trilineatum* and *Denisonia coronoides*, occur in E. New South Wales, Victoria, South Australia and Western Australia; two species, *Leiopisma eutrecasteauxi* and *Tiliqua nigrolutea*, occur in E. New South Wales, Victoria and SE. South Australia; one species, *Denisonia superba*, in S. Victoria and SE. South Australia; and one species, *Notechis ater*, on the South Australian islands, Yorke and Eyre Peninsulas and Flinders Ranges, South Australia and S. Western Australia. Thus all the present King Is. species were apparently wide ranging during the last glacial period. This suggests that only the ecologically tolerant reptile species were able to utilize the W. side of the Bassian landbridge.

Twelve species of reptiles are known to occur on Flinders Is. and 8 species (discussed above) are shared with King Is. The remaining four species are all shared with Tasmania. Only two of these species are shared with the Australian mainland: one species, *Amphibolurus diemensis*, occurs in E. New South Wales and SE. Victoria; the other species, *Rhodona bougainvilli*, occurs in S. Victoria and South Australia. The two species not shared with the Australian mainland, *Leiopisma ocellatum* and *L. pretiosum*, are endemic to Tasmania and the E. Bass Strait islands (Rawlinson, unpublished). Thus the four species occurring on Flinders Is. but not shared with King Is., were apparently of restricted distribution

during the last glacial period. This suggests that the E. side of the Bassian landbridge was generally more suitable as a corridor for reptiles.

From the above data it can be seen that there apparently was a difference between the E. and W. sides of the Bassian landbridge. On the basis of amphibian distributional data, Littlejohn & Martin (1965) made a similar observation. They concluded from a knowledge of the ecology of the species concerned that this difference indicated the W. side of the landbridge was wetter than the E. side. The reptile faunas of the two islands are generally similar and the differences observed are probably due to the much greater ecological diversity of the E. side of the landbridge. The present chain of granite outcrops from Wilson's Promontory to Tasmania shows that the unique habitats of the E. side would have been continuous down the landbridge.

## 2. Comparison of the reptile faunas of Flinders and King Islands with those of Tasmania and S. Victoria

King Is. has 8 species of reptiles (Table 1) and all are shared with Tasmania. Seven of the species are also shared with S. Victoria (*Notechis ater* being the absentee). From Table 1, it can be seen that 6 Tasmanian and 33 S. Victorian species of reptiles do not occur on King Is. This evidence indicates that the King Is. reptile fauna is allied to the present day Tasmanian reptile fauna.

Flinders Is. has 12 species of reptiles (Table 1) and all are shared with Tasmania. Nine of the species are also shared with S. Victoria (*Leiopisma ocellatum*, *L. pretiosum* and *Notechis ater* being the absentees). From Table 1, it can be seen that 2 Tasmanian and 31 S. Victorian reptile species do not occur on Flinders Is. This evidence indicates that the Flinders Is. reptile fauna is closely allied to the present day Tasmanian reptile fauna.

From the above data and Tables 1 and 2, it can be seen that while the reptile faunas of King and Flinders Islands bear a resemblance to that of S. Victoria, distributional evidence indicates that the island faunas arose from the same source allied to the present day Tasmanian reptile fauna.

## 3. Comparison of the reptile faunas of Tasmania and S. Victoria

Tasmania has 14 species of reptiles and 11 are shared with S. Victoria (Tables 1 and 2). Of the remaining three species, one (*Notechis ater*) is shared with the Bass Strait islands, South Australian islands and mainland, and Western Australian mainland; and the other two (*Leiopisma ocellatum* and *L. pretiosum*) are shared with Flinders Is. only.

Thus 29 of the 40 S. Victorian reptile species are not shared with Tasmania (or the Bass Strait islands). Consideration of the history of this area over the last 12,000 years as outlined by Littlejohn & Martin (1965) suggests that these 29 unshared species may be post-glacial intrusives into S. Victoria. However, the presence of a species in S. Victoria and its absence from Tasmania or the Bass Strait islands, is not really sufficient justification for classifying a species as a post-glacial intrusive. In general there are two reasons why a species presently occurring in S. Victoria but absent from Tasmania may not have been able to utilize the Bassian landbridge. In the first place, many S. Victorian reptiles are restricted to the far E. or far W. parts of the state and thus probably did not occur in the area of the landbridge. Secondly, the ecological preferences of some species may have prevented their southward expansion along the landbridge.

On this basis only 4 S. Victorian species may be classified as post-glacial intrusive elements with any degree of certainty. It is considered that if these species showed their present distributions when the landbridge was available, they would

have reached Tasmania. The 4 species in question are *Leiopisma guichenoti*, *Siaphos maccayi*, *Sphenomorphus quoyi tympanum* and *Notechis scutatus*, all of which are abundant across S. Victoria, and all also occur on Wilson's Promontory and Cape Otway.

The other 25 species occurring in S. Victoria but not in Tasmania are primarily forms whose main distribution lies outside S. Victoria. Their present distributions or habitat preferences would have excluded them from the Bassian landbridge. They may be classified as being of E. or W. origin according to whether the species concerned has a generally E. or W. distribution. For example, *Physignathus lesueuri*, being distributed down the E. coast of Australia into SE. Victoria, is of E. origin; *Amphibolurus barbatus*, being distributed throughout the inland arid regions of Australia into SW. Victoria, is of W. origin.

Fourteen E. and 11 W. forms, as defined above, were probably unable to use the Bassian landbridge. The E. group comprises: *Chelodina longicollis*, *Amphibolurus muricatus*, *Physignathus lesueuri*, *Egernia cunninghami*, *E. saxatilis intermedia*, *Emoia spenceri*, *Leiopisma mustelinum*, *L. weeksae*, *Sphenomorphus* sp. nov., *Tiliqua scincoides*, *Varanus varius*, *Denisonia nigrescens*, *Denisonia* sp. nov. and *Pseudechis porphyriacus*; and the W. group includes *Amphibolurus barbatus*, *Tympanocryptis lineata*, *Phyllodactylus marmoratus*, *Dehna inpar*, *Ablephaeus lineocellatus*, *Egernia luctuosa*, *Hemiergis decresiensis*, *Sphenomorphus lesueuri*, *Tiliqua rugosa*, *Demansia textilis* and *Denisonia flagellum*.

Thus it can be seen that while there has been a change in the reptile fauna of S. Victoria over the last 12,000 years, only 4 species can be listed as post-glacial intrusives with any confidence.

#### 4. Determination of the zoogeographic position of Tasmania

In order to determine the zoogeographic affinities of Tasmania and the Bass Strait Islands, their reptile fauna should be compared with that of an area of known zoogeographic composition. Rawlinson (1966) has demonstrated that Gippsland (SE. Victoria) is a typical Bassian area. Comparison of the Tasmanian reptile fauna with that of Gippsland may therefore reveal its zoogeographic position.

There are 14 species of reptiles in Tasmania (Tables 1 and 3). Eleven of these species are shared with Gippsland which has 31 species. The shared species are: *Amphibolurus diemensis*, *Egernia whitei*, *Leiopisma delicata*, *L. entrecasteauxi*, *L. metallicum*, *L. trilineatum*, *Rhodona bougainvilli*, *Tiliqua casuarinae*, *T. nigrolutea*, *Denisonia coronoides* and *D. superba*.

Seven genera of reptiles occur in Tasmania and all are shared with Gippsland which has 16 genera. The shared genera are: *Amphibolurus*, *Egernia*, *Leiopisma*, *Rhodona*, *Tiliqua*, *Denisonia* and *Notechis*.

Three families of reptiles occur in Tasmania and all are shared with Gippsland which has 5 families (Table 3). The shared families are: *Agamidae*, *Scincidae* and *Elapidae*.

In summary, it can be seen that 79 per cent of the species, 100 per cent of the genera and 100 per cent of the families of reptiles in Tasmania also occur in Gippsland. Thus there are great similarities between the reptile faunas of these two areas and, as Tasmania has only two truly endemic species (*Leiopisma ocellatum* and *L. pretiosum*), it must be considered as zoogeographically allied to mainland SE. Australia. Following Rawlinson (1966), the Tasmanian and Bass Strait island reptile faunas are Bassian in nature.

### Conclusions

From the preceding discussion and Tables 2 and 3, it is possible to draw four conclusions:

1. The E. side of the Bassian landbridge present during the last glacial period provided a more favourable habitat for reptiles than the W. side.
2. The present day reptile faunas of Flinders and King Islands were derived from the same source as the present day Tasmanian reptile fauna.
3. At least four of the present day S. Victorian reptile species are post-glacial intrusives.
4. The Tasmanian and Bass Strait island reptile faunas may be classified as Bassian (*sensu* Rawlinson 1966).

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## THE VERTEBRATE FAUNA OF THE BASS STRAIT ISLANDS:

### 3. THE GALAXIID FISHES OF FLINDERS AND KING ISLANDS

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#### Introduction

This paper represents the third of a series on the vertebrate fauna of the Bass Strait Islands. Previous parts are by Littlejohn & Martin 1965 (amphibia), and Rawlinson 1967 (reptiles).

Flinders and King Islands are the two largest islands in Bass Strait. Respectively, they represent an E. and W. remnant of a landbridge which joined Tasmania to the Australian mainland during the last glacial period (Littlejohn 1964, and included authors). The landbridge was probably also present during earlier Pleistocene glacials.

Flinders Is. was visited by the author in October and November 1962, and King Is. in March 1964. Collecting, which was by angling and by use of a dip net, was concentrated mainly on the upper sections of the streams.

Museum material has provided additional records. Collections have been examined in the Australian Museum, Sydney (AM), the National Museum, Melbourne (NM), the Queen Victoria Museum, Launceston (QVM), the Inland Fisheries Commission, Hobart (IFC), and the University of Melbourne Zoology Department (MUZD).

Literature records are few in number; those noted are by Spencer (1888) and Johnston (1888) for King Island, and by Scott (1936) for Flinders (and Clarke) Islands.

Localities referred to in the text are illustrated in Fig. 1 and 2 in Littlejohn & Martin (1965), except for Yellow Rock Creek (near East Wickham, King Is.), and Threc Rivers (approximately 3 miles N. of Currie, King Is.).

#### Inland Water Habitats on Flinders and King Islands

On King Is. and most of Flinders Is., drainage basins are of low relief and streams are mainly slow-flowing with intermittent pools, the water often being stained a red-brown colour by humic acids. In the SE. of King Is. a raised shore platform is backed by a short steep escarpment which temporarily increases stream gradients and some falls occur.

On Flinders Is., the granitic Strzelecki Peaks (2,250 ft) receive the highest annual rainfall of the island (estimated 34 in. maximum—Littlejohn & Martin 1965), and are drained by clear flowing rocky streams with intermittent falls, usually not greater than 10 ft in height. An exception is a fall approximately 80 ft high draining a small plateau in the headwaters of the Samphire Creek.

Numerous coastal lagoons backing longshore dunes are present on both King and Flinders Islands. In many of these the water is brackish.

TABLE 1

Summary of the distribution of galaxiid fishes in the Bass Strait area  
(++ wide distribution; + restricted distribution)

	SE. Australia	Flinders and King Is.	Tasmania
<i>Galaxias attenuatus</i>	++	++	++
<i>G. truttaceus</i>	++	++	++
<i>G. coxii</i>	++	+	++
<i>G. ornatus</i> group	++	—	+
<i>Brachygalaxias</i>	+	—	+
<i>Paragalaxias</i>	?	—	+

### Galaxiid Fish Fauna

#### FLINDERS ISLAND

##### GALAXIIDAE

#### *Galaxias attenuatus* (Jenyns)

SPECIMENS EXAMINED: Pratts River, 28.x.62 (MUZD); Killiecrankie Creek, 28.x.62 (MUZD).

LITERATURE RECORD: Scott (1936).

#### *Galaxias coxii* Macleay

SPECIMENS EXAMINED: Samphire Creek, 1 mile SE. of Strzelecki Peaks, 29.x.62 (MUZD); Rhodes Creek, 7 miles from Whitemark on road to Loccota, Oct. and Nov. 1962 (MUZD).

#### *Galaxias truttaceus truttaceus* (Cuvier)

SPECIMENS EXAMINED: Pratts River, 28.x.62 (MUZD); Pats River, 29.x.62 and 30.x.62 (MUZD); Rhodes Creek, 7 miles from Whitemark on road to Loccota, 26.x.62 (MUZD), and 23.i.38 (AM, IA 7413).

LITERATURE RECORDS: Scott (1936) (? subspecies); Scott (1940), Rhodes Creek, 16.i.38.

#### KING ISLAND

##### GALAXIIDAE

#### *Galaxias attenuatus* (Jenyns)

SPECIMENS EXAMINED: Three Rivers, 12.xi.62 (MUZD); Ettrick River, 24.iii.64 (live specimens in possession of R. Strickland, Marshalls Road).

LITERATURE RECORDS: Spencer (1888) (also recorded as *G. delicatulus*); Johnston (1888).

#### *Galaxias coxii* Macleay

SPECIMEN EXAMINED: Pegarah?, 1962 (specimen in possession of E. O. G. Scott, Launceston, Tasmania).

#### *Galaxias truttaceus truttaceus* (Cuvier)

SPECIMENS EXAMINED: Camp Creek, Currie, Dec. 1906 (NM), and 12.xi.62 (MUZD); Ettrick River, 24.iii.64 (live specimens in possession of R. Strickland, Marshalls Road).

LITERATURE RECORDS: Spencer (1888) (also recorded as *G. ocellatus*); Johnston (1888); Scott (1940), Currie, 19.v.34.

### Discussion

#### NEW RECORDS

*Galaxias coxii* Macleay is here recorded for the first time from both the Bass Strait Islands and Tasmania. The identification is based on comparison of the Flinders and King Is. fish (*supra*) and series from the N. (Romaine Ck.) and E. (Pine Ck.) of Tasmania (IFC) with series from the Australian mainland (Wilson's Promontory and Shoalhaven R., MUZD). Both the Bass Strait Is. and Tasmanian specimens are considered to be conspecific with the mainland samples (Frankenberg unpublished obs.).

#### DISTRIBUTION AND ABUNDANCE

*G. truttaceus* and *G. attenuatus* are abundant on both islands in the lower sections of the streams (e.g. Pratts R., Flinders Is.). *G. truttaceus* appears to penetrate further inland, particularly where stream gradients are steeper (e.g. Rhodes Ck., Flinders Is.). *G. coxii* was found in only two streams on Flinders Is., both draining the Strzelecki Peaks. In one of these (Rhodes Ck.), *G. truttaceus* was replaced upstream by *G. coxii* approximately 200 yards above the Loccota-Whitemark road; their ranges did not appear to overlap. The record of *G. coxii* from King Is. is based on only one specimen.

#### COMPARISON WITH MAINLAND AND TASMANIAN GALAXIIDS

At the superspecies level (*sensu* Mayr 1963), 5 or possibly 6 groups of galaxiids have achieved a trans-Bass Strait distribution. Only 3 of these are represented on Flinders or King Is., but in each case, the same species occurs on both Tasmania and the Australian mainland, i.e. *G. attenuatus*, *G. coxii*, and *G. truttaceus*. Distribution of the species groups in the Bass Strait area is summarized in Table 1.

Groups not represented on Flinders or King Is. are the *G. ornatus* species group and the genera *Brachygalaxias* and *Paragalaxias*. The trans-Bass Strait distribution of *Paragalaxias* is, however, open to question as the mainland record is based on only one specimen doubtfully recorded from New South Wales (Scott 1935).

The distribution of *Brachygalaxias* is outlined by Frankenberg (1966). *B. pusillus* Maek, in Victoria is typically found in low-lying swampy country, commonly in association with the pygmy perch (*Nannoperca australis* Gunther) (Frankenberg, unpublished observations). This last species has been recorded on King Is. (Johnston 1888), and it is possible that further collecting may reveal the presence of *Brachygalaxias*.

The *G. ornatus* species group includes the nominal species *G. ornatus* Castelnau of Victoria and *G. johnstoni* Scott of Tasmania (Frankenberg, unpublished data).

It is considered unlikely that this group (if present on Flinders or King Is.) could have escaped notice. In SE. Australia, members of this group are typically found further upstream than, and rarely sympatric with, *G. coxii* (where both occur in the same stream), and are particularly abundant in the Australian Alps up to 6,000 ft above sea level (Frankenberg, unpublished data). On Flinders Is., *G. coxii* was taken at the base of the 80 ft waterfall in the headwaters of the Samphire Ck., but no fish were found above the fall. Similarly, Rhodes Ck. was followed upstream, but no fish were found above (or overlapping) the range of *G. coxii*.

In conclusion, it would appear that (with the exception of *Brachygalaxias*) the distribution and relative abundance of the galaxiid fishes on Flinders and King Islands largely reflects the reduced diversity of environments on these islands when compared with the Australian mainland. Optimum conditions for dispersal across Bass Strait would probably have coincided with the formation of a landbridge during glacial maxima. The galaxiids as a group, however, are euryhaline, and the value of the landbridge would appear to lie more in its effect in directing coastal currents than in providing a means of dispersal through fresh water.

### Acknowledgements

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## TENTACULITIDS FROM NEW SOUTH WALES, AUSTRALIA

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## Abstract

Tentaculitids found in New South Wales are described and classified according to their structure, determined microscopically where their state of preservation allows. *Tentaculites ornatus* Sowerby occurs in Silurian (Wenlockian) strata at Yass. *Tentaculites chapmani* n. sp. and *Nowakia* aff. *acuaria* (Richter) occur together in Lower Devonian limestone at Ravine on the Yarrangobilly River, in the Garra Formation at Wellington and in the Taemas Stage of the Murrumbidgee Series near Taemas Bridge.

aff. *Volynites russiensis* G. Ljaschenko and *Nowakia* aff. *acuaria* (Rich.) are recorded together from limestone of either Silurian or Devonian age at Eurimbula; the former is recorded from a bore at Louth, and from the Manildra Formation of Upper Silurian age at Cudal. A table summarizing these occurrences is included.

Tentaculitids from other localities are described generically, but cannot be placed specifically because of poor preservation.

Tentaculitids are recorded from one bore. Other specimens are from surface outcrops.

## Introduction

Tentaculitids have been found in most countries, the oldest having been recorded from the Ordovician (Tremadocian) of the United States (Fisher & Young 1955). They are widespread in rocks of Silurian and Devonian age and become extinct in the Late Devonian; they occur in Silurian and Devonian strata in New South Wales.

Tentaculitids are small, sharply conical annulated shells, varying in length from a few millimetres up to several centimetres. They are not attached to any foreign body and are usually straight, though a number of those studied in this work have their proximal tips slightly bent. The shell walls vary in thickness from about 0.2 mm to 0.01 mm.

A study of New South Wales tentaculitids was undertaken with the objects of describing them, and of determining their usefulness for zoning the formations in which they occur. A zonation table cannot be set up until a taxonomic and stratigraphic analysis is performed. This paper initiates such a study.

Among the few previous references to tentaculitids from New South Wales is a listing by W. B. Clarke (1860, p. 286) of *Tentaculites ornatus* (identified apparently by Salter), *T. annulatus* and *T. ? tenuis*. Localities and authors are not mentioned.

In 1881, R. Etheridge Jr. described and figured a tentaculitid which had been found by Professor Liversidge at 'Holmes Paddock on the Macquarie below Wellington'. Two specimens from this locality, one of which is now registered as PG 4513, were among a group of fossils presented by Liversidge to the British Museum.

W. S. Dun (1898) described and figured *Tentaculites* cf. *bellulus* Hall which had been obtained from boulders at White Cliffs opal fields, and E. D. Gill (1940), when describing a trilobite from Cootamundra, recorded among other fossils from the same locality, *Tentaculites* aff. *tenuis* Sowerby. The specimens from these localities are referred to again in this paper.

### Stratigraphic Value

After careful study of the group, the Russian palaeontologist G. Ljaschenko (1959, p. 140) considers '*Tentaculites* answer the essential demands required of a fauna which will be of value for stratigraphy'. She states (p. 147) that certain species are restricted to a fraction of a stratigraphical zone in the U.S.S.R. and thus different horizons are characterized by different species of tentaculitids. They are not confined to a particular lithological type and occur in large, often enormous, numbers from littoral to deep-water facies. Fossils such as goniatites or brachiopods, which have been used as zone fossils, may be found only in certain rock facies. As tentaculitids seem not to be so restricted (Ljaschenko 1965, p. 98) they appear to be more useful as zone fossils.

Ljaschenko made use of tentaculitids to work out a detailed sub-division of the Devonian deposits of the Central and Eastern Districts of the Russian Platform. She gives tables (1959, p. 138; 1965, p. 100) with eighteen to twenty divisions in the Devonian each characterized by one or more different species of *Tentaculites*, *Nowakia*, *Styliolina*, etc. (The spelling of the word as '*Nowakia*' has priority over '*Novakia*' (Prantl and Bouček, 1960), though the spelling '*Novakia*' is used by Ljaschenko in fossil names given in Latin script in her Russian texts. She transliterates her own name as author of a species she is describing, to 'Ljaschenko'. Therefore that spelling is used here.)

Tröger (1959) pointed out that in East Thuringia, tentaculitids are the most common macrofossils in the Upper Silurian and the Devonian and that since there is a regularity in the distribution of individual species, they could be used for the classification of the rocks of these ages. He drew up a short table.

Bouček and Prantl (1960) suggested the use of tentaculitids as zone fossils in Bohemia instead of goniatites which serve for characterizing the sub-divisions of the Lower Devonian (Gedinnian, Siegenian and Emsian) of the Rhenish geosyncline, since the goniatites have proved unusable in Bohemia. They pointed out that tentaculitids are particularly suitable in the classical Barrandian area because quite a different association of tentaculitids appears in the Dvorce-Prokop limestones above the Silurian-Devonian boundary from that in the Lochkov limestone below it (p. 94). They also remarked that different species of tentaculitids (*Nowakia*, etc.) characterize different formations in the Lower and Middle Devonian.

Bouček's 'The *Tentaculites* of Bohemia' (1964) is a study of the tentaculitids occurring in Silurian and Devonian limestones and shales. A few were described by Barrande (1852, 1867) and some others by Novak (1882). Bouček's work revises earlier determinations and describes new species—thirty-eight in all. These are all thin-walled, presumably pelagic forms, whereas in New South Wales and on the Russian Platform, both thick-walled *Tentaculites* and thin-walled *Nowakia* have been found (sometimes together on the same slab in New South Wales, see Pl. 38, fig. 13). By the use of these thin-walled forms, Bouček has been able to sub-divide the Upper Silurian and Lower and Middle Devonian into twelve zones each characterized by different species. It has yet to be determined whether these zones can be found in the Silurian and Devonian in other countries.

Zagora (1962, 1964) taking the 'classic researches of Rh. Richter (1854) and O. Novak (1882) as basic', has redescribed thin-walled tentaculitids from Thuringia, and having investigated their stratigraphic occurrences, has found that a number of zones can be set up in the Upper Silurian and Devonian, each characterized by different assemblages of tentaculitids.



### Zoological Affinities and Classification

The correct zoological classification of tentaculitids is uncertain because nothing is known of their soft parts nor of the relationship of their shells to animals living today.

By various authors, at different times, they have been placed among brachiopods, foraminifera, annelida, cchinodermata, gasteropods and pteropods and even in other groups. There has been no general agreement about any of these allocations.

Thomas Austin's view (1845) that they were pteropods was generally adopted after that date, though sometimes without conviction. Giving no evidence, he wrote 'on a careful examination of numerous specimens I am of opinion that the *Tentaculite* is the shell of a Pteropodous mollusk allied to the recent *Creseis* as the *Conularia* is that of an animal allied to the *Cleodora*'.

An argument against their being pteropods was the long gap in time between the dying out of tentaculitids in the Devonian and the appearance of fossils universally accepted as pteropods in the Tertiary. Further, the thick shells of *Tentaculites* (s.s.) are quite unlike those of most pteropods. The remarks of R. Etheridge Jr. (1881) against this allocation are recorded later.

W. B. Clarke (1860) placed them in the Annelida, as did some other workers. The straight shells of tentaculitids and their mode of living unattached to foreign objects are some of the factors cited against these shells being formed by worms. The extinction of tentaculitids in the Late Devonian also seems to argue against their being formed by tubicolous worms which continue until the present day.

G. P. Ljaschenko (1955, 1957, 1958a, 1959) set up a new class, the Coniconchia, as a result of her exhaustive study of Devonian tentaculitids obtained from surface outcrops and from sub-surface cores in the U.S.S.R. She has also studied a small number of Silurian tentaculitids (1958b). The new class Coniconchia contained two super-orders, Tentaculitoidea and Hyolithoidea. The super-order, Tentaculitoidea, was divided into the orders, Tentaculitida, Styliolinida and Novakiida. The class, Coniconchia, was referred to the Mollusca (?) (Ljaschenko 1957, p. 84), but in the diagnosis given at the beginning of her 1959 volume, it is referred to Mollusca without query.

Fisher (1962) disagreed with the placing of hyolithids and tentaculitids in a single class as Ljaschenko had done and he set up a new class of the Mollusca, the Cricoconarida, comprising the orders, Tentaculitida and Dacryoconarida. He pointed out that there are already in use many variations of the word 'tentacle' for unrelated animals and that a new word, Cricoconarida, avoids confusion. He uses the word, Tentaculitida for the name of an order, because of previous broad usage, especially by Ljaschenko. He placed hyolithids and related forms in a new class, the Calyptotomatids.

Bouček (1964) rejected Fisher's new class name, Cricoconarida, introducing yet another name, Tentaculita. He considered that the use of a traditional name would cause no confusion. He retained Fisher's ordinal names and added three others. Bouček separated the orders mainly on the character of the shell wall and on the nature of the embryonal chamber.

I have followed Bouček's ordinal classification in this paper, but am describing representatives of two orders only, the Tentaculitida G. Ljaschenko 1955 and Dacryoconarida Fisher 1962.

The Tentaculitida possess shells with relatively thick multi-layered walls. The outer layers are transversely folded into annulations and are pierced, partway, by canals. The inner layers are smooth or only slightly annulated and are not pierced.

Bouček (1964, p. 51) states 'longitudinal striation is not developed', but I have seen some indication of longitudinal markings in specimens having a conical initial chamber, mentioned later in this paper.

The Daeryoconarida have shells with very thin walls which are not pierced by canals. The walls are bent into rippling transverse swellings and contractions which may be repeated on the internal surface. Longitudinal striations are often present. The initial chamber is tear-drop like.

The sub-ordinal classification of Ljaschenko (1958a) is followed in this paper. Families are separated according to the situation of the annulations, whether they are uniform or non-uniform; sub-families on the thickness of the shell-wall and the character of the internal cavity. Genera and species are separated according to finer features and details of sculpture.

In members of the family Tentaculitidae Walcott 1886 described in this paper, there are annulations of different sizes and the arrangement of these with respect to one another distinguishes the genera.

The only member of the order Daeryoconarida Fisher 1962 described here has the characters of the order.

### Glossary of Terms

**Tentaculitid** signifies any member of the Class Tentaculita Bouček 1964.

**Angle of growth**, as used in this paper, is the angle between the sides of the conical shell which contained the main body of the animal, that is, between the shell walls as they approach the aperture.

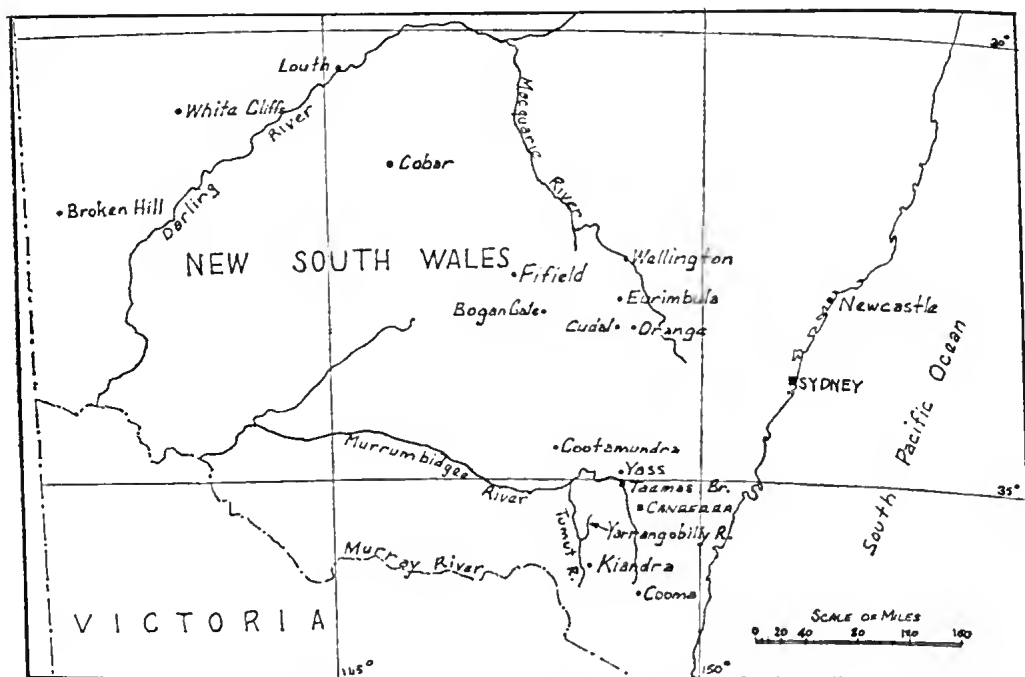


FIG. 1—Locality Map of New South Wales.

**Annulation** describes the large, parallel ring-like protuberances circling the shells of members of the order Tentaculitida G. Ljaschenko 1955.

**Cast** is used to indicate the material which replaced the body of the original animal and which carries its markings.

**Mould** means the cavity from which the body of the animal has been dissolved.

**Riblets** are the small, fine rings between the annulations.

**Striations** are longitudinal flutings on the shell.

**Swellings** and **Contractions** are the transverse billowing ripples on the shells of members of the family Nowakiidae Bouček and Prantl 1960.

### Ecology

Members of the Tentaculitidae Walcott 1886 and Nowakiidae Bouček and Prantl 1960 have been found in New South Wales. Tentaculitidae have been sometimes found alone and sometimes with Nowakiidae. Nowakiidae have not been found alone, but no conclusion can be drawn from this fact, because tentaculitids have, as a rule, been collected only incidentally to other fossils and little intensive search for them has been made. Findings have been made in surface outcrops of limestone, sandstone, siltstone and quartzite, and in one case from a bore through calcareous shale.

Most of the tentaculitids described here came from limestones with associated brachiopods, corals, crinoids, ostracods, etc. Nowakiids have been found only in limestones.

The most prolific occurrence of tentaculitids yet seen in New South Wales is at Cootamundra in a fine-grained white to yellowish-green Silurian siltstone. Unfortunately they are almost invariably found as moulds. When occurring in large numbers, the tentaculitids are alone, but in other specimens of the same rock from Cootamundra, a few occur with brachiopods, lamellibranchs, trilobites, etc. (Gill 1940; Sherrard 1960).

In several cases in western New South Wales, traces of tentaculitids have been found as moulds or, rarely, as replacements in sandstone or quartzite.

Observers have frequently remarked on the lack of relationship of tentaculitids to facies, thus making them potential zone-markers. However, Bouček (1964, p. 157) discusses 'the serious problem' of the simultaneous occurrence of thick- and thin-walled tentaculitids in some rocks. The former should be limited to an environment which, though on the sea floor (or benthonic) is only of shallow depth and therefore rich in oxygen, while the latter are typical of different conditions. He admits, however, that thin-shelled forms are not absent from shallow benthonic areas. Conditions in New South Wales where thick- and thin-shelled tentaculitids occur together (Pl. 38, fig. 13), though not in vast numbers, seem to illustrate such a shallow, benthonic environment.

Fisher (1962) suggests that the Tentaculitidae were nekto-benthonic while Nowakiidae were planktonic.

Though tentaculitid shells in the rocks here examined lie generally on parallel planes, this is not always the case. Polished slabs and thin sections of limestones show both longitudinal and transverse sections of tentaculitids lying beside each other (Pl. 38, fig. 8). This condition contradicts a statement of Fisher (1962, p. 104) that 'Cricoconarid shells always lie parallel to bedding of strata that enclose them . . . this strongly denies a fossorial habit'. Conditions on coral reefs, from which some of these tentaculitid-bearing limestones probably come, might cause tossing about of shells after the death of the animal, resulting in a final

random arrangement. Such conditions also probably caused the insertion of smaller shells into larger ones (Pl. 37, fig. 2, 3).

### Study of Tentaculitids

To classify tentaculitids, it is necessary to study their shell-walls, both externally and internally, their thickness, structure and sculpture. The walls may be smooth, annulated or rippled externally with the internal surface either repeating this sculpture, or smooth. Vertical striations may appear. The walls may consist of several layers with some layers repeating annulations on the surface and some not doing so. Canals may partly pierce the walls. The initial chamber may be conical in form or rounded. The character of the internal cavity, the presence or absence of septa in it and the angle of growth of the shell must be known.

It is therefore necessary to prepare thin sections, polished surfaces, or enlarged photographs, showing longitudinal and transverse sections, to determine the distinguishing characters of the fossils.

In the study of New South Wales tentaculitids, most information has been gained where the fossil replacing material has been calcite. Little or nothing has been learned from empty moulds formerly occupied by tentaculitids, nor from some specimens where the material replacing the fossil is silica or clay.

### Systematic Descriptions

Class TENTACULITA Bouček 1964

Order TENTACULITIDA G. Ljasehenko 1955

Family TENTACULITIDAE Walcott 1886

Genus *Tentaculites* Schlotheim 1820

The members of this genus possess narrowly conical shells whose sculpture consists of rather distant transverse annulations. Spaces between these are often covered by fine riblets, chiefly developed in the second part of the shell.

### *Tentaculites chapmani* n. sp.

(Pl. 37, 38, fig. 1, 3, 4, 5, 6, 7, 12)

*Tentaculites liversidgei* Eth. fil.; Etheridge, R. Jr.; J. & Proc. Roy. Soc. N.S.W., 1881 (for 1880), xiv, 255 (*nomen nudum*).

*Tentaculites* sp. Eth. fil. *ibid* unnumbered plate, fig. 10, 10a.

HOLOTYPE: No. F43436, Australian Museum.

DESCRIPTION: The shells are of medium size, usually about 10 mm or slightly longer, straight, narrowly conical and of circular cross-section. Their surfaces are covered with regularly arranged, parallel, raised, transverse annulations of blunted, sometimes almost thorn-shaped triangular cross-section, projecting from the shell for a distance equal to about one-seventh (in the youthful stage) to nearly one-half (in the mature section) of the internal diameter of the shell. The annulations can be seen in section to slope with a slightly greater (that is flatter) angle backward to the apex than forward to the aperture.

The inter-annular areas are semi-circular near the apical end, where they are about equal in width to the annulations. They are flatter in more mature sections of the shell and the space between annulations gradually increases by about three times. Riblets are either absent or very faint on inter-annular areas near the apex, but five or six can sometimes be counted on those near the aperture. Traces of longitudinal striations can be seen on some inter-annular areas.

The wall of the shell varies in thickness from about one-seventh to one-twelfth the internal diameter of the shell (that is to nearly 0.1 mm). Its internal surface is nearly smooth in the early section of the shell but later becomes annulated, repeating the external sculpture in the apertural fifth of the shell. The wall is layered with the outer layers forming the outer sculpture while the inner layers are more nearly smooth (Pl. 37, fig. 1). There are about five layers. Thin canals, more than forty per mm, pierce the wall of the shell. They pass inward at right angles to the surface, reaching about one-third of the way to the internal surface.

Thick septa (0.1 mm wide) can be seen in very well-preserved specimens in the apical cavity (Pl. 38, fig. 4). They are horizontal near the apex, but become increasingly concave with a basin-shaped concave surface opening towards the aperture. As many as twelve have been counted.

A conical embryonal chamber forms the proximal end of the shell. There is a slight thickening of its wall, forming a constriction about one mm from the apex. The apex has a smooth internal and external wall (Pl. 38, fig. 7). The tip of the apical section is usually straight, though it may sometimes be bent or broken off. It is up to 1.3 mm long and 0.1 mm wide.

**DIMENSIONS:** Length of shell: usually up to 12 mm, exceptionally to 22 mm. Width: Apertural 0.8 mm to 1.0 mm, exceptionally to 1.3 mm. Angle of growth: about 5°.

**LOCALITIES:** Tentaculitids from five localities in N.S.W. are considered to belong to this species. Locality of holotype: Ravine, about Portion 57, Par. Selwyn, near the Yarrangobilly R., about eight miles NW. of Kiandra (also known as Upper Lob's Hole). Other occurrences: The Holmes, about Portion 36, Par. Micketymulga, near Macquarie R., about 9 miles downstream from Wellington; Macquarie Park, Portion 103, Par. Ponto on the opposite side of the river from the last locality (in the Garra Formation, Strusz 1965); Portion 65, Par. Taemas, W. side of Murrumbidgee R., 14 miles SW. of Yass, in the Taemas Stage of the Murrumbidgee Series (Browne 1959) (this is the locality named 'Shearsby's Wall-paper' by T. W. E. David, when A. J. Shearsby showed him a vertical cliff of limestone covered with fossils); Portion 208, Par. Warroo, near Taemas Bridge over the Murrumbidgee R. and on the opposite side of the river from the last locality.

**REMARKS:** Tentaculitids from the second of these localities, The Holmes, were among other fossils presented by Liversidge of Sydney University to the British Museum and described by R. Etheridge Jr., 1881. Of the two presented, one is now listed at the British Museum (Natural History) as No. PG 4513. Etheridge concluded his partial description of the tentaculitids, which mainly referred to the structure of the shell, by saying 'should this *Tentaculites*, on further examination, prove to be specifically distinct from the numerous ones which have hitherto been described, I would propose for it the name *T. Liversidgei*'. This is undeniably a *nomen nudum*. Hence a holotype has been selected from elsewhere, since although it is more than 80 years since Etheridge wrote, precise comparison of the original tentaculitid specimen with others, to determine if it is specifically distinct is still not possible. Except in the case of those described by Ljaschenko, the internal structure of *Tentaculites* has not been recorded. Conspecific relations cannot therefore be recognized and the validity of Etheridge's nominal species cannot be demonstrated.

The two illustrations of the tentaculitid which Etheridge partially described (Fig. 10 & 10a) are on an unnumbered plate accompanying his paper but are listed in the Explanation of Plate on p. 258 of Volume xiv of the J. & Proc. Roy. Soc. N.S.W. as of *Tentaculites* sp. and not of *Tentaculitids liversidgei*. Fig. 10

represents a number of tentaculitids on a slab of rock which exactly match neither specimen No. PG 4513 now in the British Museum, nor specimen No. F688 in the Fossil Catalogue of the Mining Museum, Sydney, registered as *Tentaculites liversidgei* Eth. f. from Holmes Station Paddock, Wellington (Pl. 38, fig. 5).

The present owners of the property, Mr and Mrs G. B. H. Sutherland, have kindly informed me that 'The Holmes' station was taken up about 1870 by J. A. Gairdner and consisted of portions in the Par. of Micketymulga on the N. bank of the Macquarie R., downstream from Wellington. Limestone outcrops in portions 107, 35 and 36 within what was 'The Holmes' station. The same rock, of the Garra Formation (Strusz 1965) can be traced on the S. bank of the Macquarie in Portion 103, Par. Ponto. Thin sections of this limestone show the same structure as that referred to by Etheridge in his paper of 1881.

He noticed (p. 254) that in thin section 'the shell wall was distinctly traversed by small tubuli from the exterior . . . these . . . do not penetrate quite through the shelly matter . . . I have not observed any trace of septa . . . The internal and external walls of the shells . . . correspond with one another . . . In one or two examples there does appear to be a division of the shelly matter into laminac . . . If the structure exhibited by Australian *Tentaculites* should prove to be constant throughout the genus, it showed little in common with that of a *Pteropod*.'

At the time Etheridge was writing, tentaculitids, as a rule, were considered to be pteropods. His observations on the wall structure correspond with those made by G. Ljaschenko (1959), but he missed seeing septa within the internal cavity, probably because of poor preservation of the specimens.

COMPARISON: *Tentaculites chapmani* n. sp. resembles the description given by G. Ljaschenko (1959, p. 75) for the first group of the genus *Tentaculites* Schlotheim, em. G. Ljaschenko 1954. Species in this group show large transverse rings separated by wide inter-annular areas which are smooth in the first half of the shell and usually covered with transverse riblets in the second. The internal surface of the wall is smooth in the first half of the shell and ringed in the second. *T. maslovi* G. Ljasch. from the Givetian is cited as an example of this group and from its description shows similarities with *T. chapmani* n. sp. though *T. maslovi* is considerably smaller.

MATERIAL: From all localities except 'The Holmes' and Portion 208, Par. Warroo, at least 100 specimens of *T. chapmani*, distributed on different rock specimens from each. From 'The Holmes' one specimen which contains about twenty tentaculitids. From Portion 208, Par. Warroo, one large specimen with 100 examples of *T. chapmani*. The specific name has been chosen to commemorate the name of Frederick Chapman, palaeontologist.

### ***Tentaculites ornatus* Sowerby**

(Pl. 37, fig. 2)

DESCRIPTION: The shell is of medium size, not more than 10 mm long, straight, narrowly conical, and of circular cross-section. In the apertural section its surface is covered with large, regularly arranged, parallel, transverse, raised annulations of rounded cross-section (Pl. 37, fig. 2). These are separated by inter-annular areas of semi-circular shape in the apical part of the shell, 1 to 1½ times as large as the annulations. In the more mature part of the shell, the inter-annular areas become flattened and are from 2 to 5 times as wide as the annulations. Riblets numbering 4 to 6 or more sometimes cover the inter-annular areas but cannot always be seen. Longitudinal striations can also sometimes be traced on these areas. The wall is

about  $\frac{1}{16}$  the thickness of the internal diameter of the mature part of the shell. Its internal surface is nearly smooth, only faintly repeating the external sculpture opposite the annulations. The annulations are smoothly rounded when seen in longitudinal section, standing out from the shell up to about  $\frac{1}{2}$  of its internal diameter, but usually less. In the size of the diameter in both youthful and mature parts of the shell (0.1 and 0.9 mm respectively) there are one to two annulations. The wall has three layers, which follow the external contour of the shell. They are pierced by vertical canals about 0.02 mm distant from each other. The apical end may be slightly bent. There is a total of about 20 annulations. Septa are present.

**DIMENSIONS:** Length of shell: Not more than 10 mm. Width of shell: 1.0 mm near aperture, 0.1 mm near apex. Angle of growth: About 6°.

**LOCALITY:** Hatton's Corner, Portion 7, Par. Hume, Yass.

**AGE:** Wenlock, Silurian (Brown & Sherrard 1951).

**MATERIAL:** A hand-specimen of limestone in which about one tentaculitid occurs to the square cm.

**REMARKS:** Tentaculitids found at Hatton's Corner agree well in dimensions with those in a specimen of *T. ornatus* Sowerby from the Wenlock of Dudley, England (Australian Museum specimen No. F31534) and with the dimensions given in McCoy's (1855) description of *T. ornatus* Sowerby from the same locality. They are much smaller, however, than *T. ornatus* Sowerby described by G. Ljaschenko (1958b) from deposits in the Podolia districts of the U.S.S.R. 'belonging to the uppermost part of the Ludlow stage', though both show the rounded annulations characteristic of *T. ornatus*.

### *Tentaculites* sp. No. 1

(Pl. 38, fig. 10, 11)

**DESCRIPTION:** The shell is large, up to 18 mm long, straight, narrowly conical, of circular cross-section. The surface is covered with regularly arranged parallel, asymmetric annulations of gradually increasing size and blunted triangular cross-section. The annulations are separated from each other by inter-annular areas nearly equal to them in size and of shallow crescentic form. A gradual increase in size and a flattening of the outline of these areas takes place towards the aperture. The angle of slope of the annulations is noticeably flatter apically. In the mature section, the annulations are rostrate. In this portion of the shell, the annulations project to a distance of  $\frac{1}{2}$  the internal diameter in some specimens. Fine riblets are seen on both upper and lower edges of each annulation as well as on the inter-annular areas (Pl. 38, fig. 11). Vertical striae make a faint cross-hatched pattern with the horizontal riblets on the shell's surface.

Wall-thickness varies from one-quarter to one-eighth of the internal diameter of the shell. Generally, the layered wall has a smooth internal surface though it is slightly annulated near the aperture. Partitions can be seen in the apical cavity.

**DIMENSIONS:** Length up to 18 mm; width up to 1.3 mm at the aperture, 0.25 mm near the apex. Angle of growth about 5°. Three large annulations and seven riblets occur in 1.3 mm (the size of the apertural diameter). Three annulations in 0.25 mm near the apex. Total: 45 annulations.

**LOCALITY:** ? Cavan, near Taemas Bridge, over the Murrumbidgee R., 14 miles SW. of Yass.

**MATERIAL:** One large slab, with sixty or more tentaculitids and a large '*Orthoceras*' like nautiloid. Sydney University Geological Collection No. 5891.

REMARKS: The shape of the coarse annulations in the mature section of this shell is distinct from that of any others from New South Wales so far studied, with the exception of the annulations in a tentaculitid fragment found in limestone in Portion 107, Par. of Micketymulga, near Wellington. However, a new species cannot be erected since locality is uncertain. The shape and arrangement of the annulations, the wall-thickness of the shell and its smooth internal surface suggest a comparison between this tentaculitid and *Uniconus* G. Ljaschenko, particularly with the species *Uniconus livnensis* G. Ljaschenko. But the presence of riblets on the inter-annular areas excludes this fossil from the genus *Uniconus*. This tentaculitid is also larger than any *Uniconus* described by Ljaschenko. It shows some similarity to *Dicricococonus orientalis* (Karpinsky) (G. Ljaschenko 1959, Pl. X; Fisher 1962, p. 114). That species, however, does not show fine riblets either. The fossil being described is retained for the present in the genus *Tentaculites*, but it may need reassignment later. It is possible it may be older than *T. chapmani*.

#### ***Tentaculites* sp. No. 2**

*Tentaculites* cf. *bellulus* Hall; Dun, W. S., 1898. Rec. Geol. Surv., N.S.W., 5: 160, Pl. xviii, fig. 9, 10.

DESCRIPTION: *Tentaculites* cf. *bellulus* Hall was recorded by Dun (1898) from white saccharoidal quartzite of Devonian age occurring as inliers in Cretaceous rocks at White Cliffs opal fields. Brachiopods, lamellibranchs, gasteropods and cephalopods are also present. The tentaculitids, for the most part, occur as empty moulds, though occasional fragments of silicified replacing material remain. The moulds are of shells up to 20 mm long and 1 mm wide at the aperture. Coarse transverse annulations are arranged at regular distances (about 2 in the width of the apertural diameter) and protrude about  $\frac{1}{2}$  of the total width. Riblets may be seen on the inter-annular areas.

The shells have extremely strongly developed longitudinal striations which make deep indentations on the annulations and are noticeable on the inter-annular areas also. They are much more noticeable than any of the riblets seen in tentaculitids already described in this paper. This difference may be due to the type of replacing material.

Dun does not give his evidence for assigning these tentaculitids to *T. bellulus* Hall. I cannot agree with this identification. Hall (1879, p. 169) does not mention longitudinal ornamentation in his diagnosis of *T. bellulus*, nor is it to be seen in his figure of the species. I must also differ from Dun's statement 'there appears to be little or no trace of transverse striation between annulations'. This shows clearly on plaster casts made in the moulds of tentaculitids from White Cliffs. Dun goes on to say 'there is some general resemblance to *T. ornatus* Sowerby'. The state of preservation of the specimens will allow an identification only as *Tentaculites* sp.

MATERIAL: White quartzite slabs, each with about twenty moulds of *Tentaculites* sp. in the Australian Museum and in the Sydney University Geological Collection. Moulds of tentaculitids and lamellibranchs occur also in a similar white saccharoidal quartzite found about half-way between Louth and Cobar, about 150 miles E. of White Cliffs (No. F11753, Mining Museum, Sydney). They resemble those from White Cliffs in size and longitudinal furrowing.

#### ***Tentaculites* sp. No. 3**

MATERIAL: Tentaculitids in the Bogan Gate Sandstone of the Hervey Group (Conolly 1965) from Central New South Wales have been examined from two localities, 12 miles NNW. of Bogan Gate and 12 miles ESE. of Fifield (Mining



Museum, Sydney, specimens F9785, F9787). The tentaculitids occur as moulds and casts in red sandstone which also contains moulds and casts of brachiopods.

Conolly (1965, p. 80) writes that the rocks containing these fossils are 'assumed to be of Late Middle Devonian to Early Upper Devonian age'. Material examined consisted of two slabs from each locality, each with about 20 specimens.

**DESCRIPTION:** This *Tentaculites* is rather broader (up to 1.4 mm) at the aperture than that found at White Cliffs and the annulations are not arranged so regularly (about 2 per size of the apertural diameter). Between them on the flat inter-annular areas are very well-marked fine transverse riblets (7 per size of the apertural diameter). The tube forming the apex is covered with fine transverse riblets throughout its length of 2.5 mm. The shells are up to 17 mm long. Well-marked longitudinal striations are also present, but are perhaps not so strongly marked as in tentaculitids from White Cliffs. The difference may be due to the type of replacing material. The preservation as casts and moulds does not permit a specific identification.

***Tentaculites* sp. No. 4**

*Tentaculites* aff. *tenuis* Sowerby; Gill, E. D., 1940, Proc. Roy. Soc. Vict. 52: 106.

**DESCRIPTION:** The shell is of medium size, up to 9 mm long, straight, sharply conical, with angle of growth about 5°. The cross-section is circular. The surface of the shell is covered with parallel, transverse, regularly arranged, rounded, raised annulations of two sizes. The coarser, of which two occur in the space of the apertural diameter, are separated by two to four finer riblets. The coarse annulations have a greater slope towards the aperture than to the apex. There is a suggestion of longitudinal striations across the transverse annulations and inter-annular areas on the moulds. Casts consist of clayey replacements of the shells. No internal structure can be seen in thin sections prepared from the casts, therefore no specific determination can be made from the material available: siltstone with a large number of empty moulds which once contained fossils, but with only a few fragments of casts remaining. Since plaster casts made in the moulds show coarse annulations separated by fine riblets, they can be placed in the genus *Tentaculites*, but no specific attribution can be made.

**DIMENSIONS:** Length of shell, up to 9 mm; width near aperture, 0.9 mm.

**LOCALITY & MATERIAL:** Cootamundra; blocks of siltstone in the collections of the Australian Museum, Sydney and the National Museum, Melbourne, presented by the late W. E. Williams of Cootamundra, N.S.W. Some specimens show layers of tightly packed empty moulds, in parallel arrangements. Other layers show empty moulds of tentaculitids arranged in a more random fashion (about 3 to the square centimetre) associated with other fossils. Associates are *Lingula adamsonii* Fletcher; *Grannysia obliqua* McCoy; *Leiopteria gregaria* Sherrard; *Nuculana striata* Sherrard; *Calymene* (*Gravicalymene*) *cootamundrensis* Gill. No outcrop containing the fossil-bearing siltstone could be found recently on the Temora road, 1½ to 2½ miles from Cootamundra, on Oak's Ck, the locality from which the collection is recorded (Gill 1940; Sherrard 1960).

**AGE:** Upper Silurian (Gill 1940).

**REMARKS:** Gill included *Tentaculites* aff. *tenuis* Sowerby in a list of fossils from Cootamundra accompanying the trilobite, *Gravicalymene cootamundrensis* Gill, when he was describing that species. McCoy (1855) suggested that *T. tenuis* may represent the young of *T. ornatus*. Since only empty moulds and a very few casts

of the tentaculitid from Cootamundra were available for study, the structure of the walls could not be determined. Details of the structure of the walls of *T. tenuis* Sowerby have not been published.

Genus *Volynites* G. Ljaschenko 1957

The genus *Volynites* G. Ljaschenko differs from the genus *Tentaculites* Schlotheim by the presence, on the external surface of the shell, of parallel transverse raised annulations of three different sizes. The internal wall of the shell has a step-like character.

aff. *Volynites russiensis* G. Ljasch. 1957

(Pl. 38, fig. 8, 9, 13)

*Volynites russiensis* G. Ljasch. 1957, p. 96, Pl. III, fig. 1, 2.

*Tentaculites russiensis* G. Ljasch. 1958b, p. 24, Pl. IV, fig. 1, 2.

DESCRIPTION: The shell is of medium size (up to 10 mm long), straight, narrowly conical, of circular cross-section. The surface is covered with raised, parallel, transverse annulations arranged somewhat irregularly. In the tube-like apical section, the annulations are small and equi-dimensional. In the juvenile part of the shell, larger annulations are arranged in pairs, though the members of the pair are not often of the same size. Between each member of the pair, riblets may sometimes be seen on the inter-annular area, which, in this part of the shell, has a semi-circular surface. Approaching the aperture, large annulations are arranged singly, at a distance apart about equal to the apertural diameter. Between them are one or two smaller annulations and several finer riblets. Thus, there are three orders of size in the annulations and riblets. All large annulations have an almost symmetrical, rather sharply triangular outline. They project to a distance of about one-quarter the size of the internal diameter of the shell. The inter-annular areas have a flat surface in this section of the shell and are from two and a half to five times as wide as the annulations. Faint longitudinal striations can sometimes be seen on them making a cross-hatch pattern with the fine riblets.

The wall has a thickness of between  $\frac{1}{12}$  and  $\frac{1}{20}$  the diameter of the shell. Its internal surface faintly repeats the external sculpture of the shell, and sometimes has a stepped appearance (Pl. 38, fig. 9). Layering can be seen in the wall.

Near the apex there are about six annulations in 0.15 mm (the diameter in that section). This is followed by a section nearer the aperture where there are 2 to 3 coarse annulations in 0.5 mm (width of diameter in that section). Up to ten riblets occur in some inter-annular areas. The total number of coarse annulations is about 12. The internal cavity of the shell in the apical section is divided by transverse basin-shaped partitions (Pl. 38, fig. 8). In thickness, they are about 0.02 mm ( $\frac{1}{4}$  the width of the internal diameter in that part of the shell).

DIMENSIONS: Length up to 10 mm; width at aperture 0.8 mm, near apex 0.12 mm. Angle of growth 4-6°.

LOCALITIES: Tentaculitids from four localities are considered to belong to this species. These are Portions 26 and 53, Par. Eurimbula; Portion 3, Par. Cudal (Manildra Formation, Joplin *et al* 1952); and between the 1055 and 1155 ft levels in a bore at Louth. All are in the West of the State, the first two about 35 miles NNW. of Orange, the third about 25 miles W. of Orange, and the fourth on the Darling R.

REMARKS: The specimens described here show the three orders of annulations and the stepped wall which characterize *Volynites russiensis*, though the shell wall

of the N.S.W. forms is not so thick. Its width varies from  $1/_{12}$  to  $1/_{20}$  of the internal diameter of the shell. G. Ljaschenko's plates (1958b, Pl. 4) of *Tentaculites russiensis* show width of shell wall about  $1/_{10}$  the internal diameter of the apertural end. Ljaschenko refers to similarities between *V. (T.) russiensis* Ljasch. and *T. wenlockianus* Vinc. *V. russiensis* Ljasch. is recorded from the Upper Ludlow of Western Russia.

*Tentaculites russiensis* was made the genotype of the new genus *Volynites* G. Ljaschenko 1957, but was described by her (1958b) as *Tentaculites russiensis* G. Ljasch. Fisher (1962) cites *Volyutes* Lyashenko (Note: Fisher transliterates the Russian author's name thus) as a genus of the family Tentaculitidae Walcott 1886.

**MATERIAL:** Four specimens from the second locality given above, showing about 24 specimens of aff. *V. russiensis* in all. One specimen from each of the other localities, each with about 12 specimens. At least 20 specimens in bore.

#### Order DACRYOCONARIDA Fisher 1962

The species already described belong to the genus *Tentaculites* Schlotheim or seem to be affiliated to the genus *Volynites* G. Ljaschenko, that is they are thick-walled forms. In addition to these there are found, sometimes on the same slabs with thick-walled forms in N.S.W. (Pl. 38, fig. 13), thin-walled forms belonging to the Order Daeryoconarida Fisher 1962, Family Nowakiidae Bouček & Prantl 1960.

Specimens of this family in N.S.W. are incomplete proximally and sometimes only the casts are preserved. They are up to 5 mm long and 0.5 mm wide and show more or less regular swellings separated by contractions which are crossed by up to 20 discontinuous longitudinal striations. The walls are thin, varying between 0.01 and 0.03 mm.

Bouček (1964, p. 67) writes that 'it is not excluded that *Tentaculites matlockiensis* Chapman, redescribed by Gill (1941) which is recorded from Victoria, also belongs to the Family Nowakiidae.

In Czechoslovakia (Bouček 1964) and Thuringia (Zagora 1962, 1964) only thin-walled forms have been recorded. On the Russian Platform, the thin-walled forms *Viriatella*, *Crassilina* and *Styliolina* are recorded (G. Ljaschenko 1959) as occurring with thick-walled *Tentaculites* and *Dicricocoonus* Fisher. *Nowakia karpinskii* G. Ljasch. is recorded from the Lower Eifelian with no accompanying thick-walled tentaculitids. Descriptions of tentaculitids from other countries do not give enough detail for comparison.

Bouček (1964, p. 157) as mentioned earlier, has come to the conclusion that though thin-walled forms of tentaculitids probably preferred living in deep sea zones, they could not have been entirely absent from benthonic, shallow areas where thick-walled forms lived. Such conditions must have prevailed in N.S.W. where thick- and thin-walled forms apparently lived together.

I concluded that the thin-walled tentaculitids from New South Wales are affiliated to *Nowakia acnaria* (Richter) from the Czechoslovakian Lower Devonian. They are similar in size, in shape and number per mm of the swellings and contractions of the shell wall when seen in longitudinal section. The wall in both is of about the same thickness and the angle of growth is equal.

The sculpture of the swellings and contractions is more pronounced than that seen in *Paranowakia* Bouček or in *Viriatellina* Bouček. Longitudinal striations are developed on the N.S.W. thin-walled tentaculitids to about the same extent as in

*Nowakia acuaria* (Richter) from Czechoslovakia. Other species of *Nowakia* found in younger Devonian formations in Czechoslovakia show much stronger longitudinal striation than that shown in specimens of *Nowakia* from N.S.W.

I sent specimens of *Nowakia* from New South Wales to Professor Bouček of Czechoslovakia in answer to a request from him. He does not agree that *Nowakia* from Ravine is conspecific with *N. acuaria* (Richter), but he thinks that it is almost the same as a species of *Nowakia* found in Czechoslovakia in the Uppermost Emsian (Zlichovian) horizon of the Devonian.

#### Genus *Nowakia* Gurich 1896

The members of this genus have short, narrowly conical shells which have a larger angle of growth than shells of the genus *Tentaculites* Schlotheim. The walls of the shells are thin and are transversely folded into rippling swellings and contractions which are repeated on the internal wall. Longitudinal striations are also present.

#### *Nowakia* aff. *acuaria* (Richter 1854)

(Pl. 38, fig. 13, 14, 15)

**DESCRIPTION:** The shell is small (up to 5 mm long), straight, acutely conical and of circular cross-section. It is usually black but sometimes bleached to white. The surface is covered with low, obtusely angled, rounded or pinched-out right-angled, transverse swellings separated by contractions which are up to twice as wide as the swellings (Pl. 38, fig. 14, 15). There are usually between 20 to 30 swellings in the length of the shell, at times inequidistant, three to five in the width of the diameter of the shell. They protrude from the shell surface about  $\frac{1}{7}$  the width of the internal diameter of the shell. The wall is thin, about 0.01 mm. The internal surface of the wall of the shell is also rippled, exactly repeating the external sculpture. With high magnification a two-layered structure can be seen.

Longitudinal striations are noticeable on the external shell-surface. These make indentations on the summits of the swellings and can be seen on the contractions, but are not continuous for the length of the shell. There are 5 to 10 across the diameter of the shell.

**DIMENSIONS:** Length: up to 5 mm, but usually 2 to 3 mm. Incomplete proximally. Width at aperture up to 0.5 mm, usually 0.3 mm. Angle of growth: 7 to 12°.

**LOCALITIES:** Portion 57, Par. Selwyn, near Kiandra (Ravine or Upper Lob's Hole); Portion 103, Par. Ponto, near Wellington; Portion 65, Par. Taemas (Shearsby's Wall-paper), near Yass; Portion 26, Par. Eurimbula, about 35 miles from Orange.

**MATERIAL:** From the first and third of these localities about 30 specimens have been obtained; from the second and fourth localities about half a dozen each. All occur on the same slabs as thick-walled tentaculitids.

#### Stratigraphical Implications

An aim in this study was to commence the compilation of a stratigraphic table of tentaculitids from New South Wales. Such a table is necessary to determine the potential use of tentaculitids as zone fossils.

In the Hume Limestone at Hatton's Corner, Yass, in the Wenlock Formation of the Silurian, *Tentaculites ornatus* Sowerby has been identified. The dimensions of *T. ornatus* from Hatton's Corner are much the same as those of *T. ornatus* from Dudley, England, in the Wenlock, the type locality for Sowerby's species. *T.*

TABLE

The following table has been prepared, showing Tentaculitids described in this paper from their formations and presumed age assignments.

	Middle to Upper (Conolly, 1965)	Sandstone, Bogan Gate	<i>Tentaculites</i> sp. No. 3
DEVONIAN	Lower	1. Limestone, Ravine, Yarrangobilly R.	<i>Tentaculites chapmani</i> n. sp.
		2. Wellington, Garra Formation (Strusz 1965)	<i>Nowakia</i> aff. <i>acuaria</i> (Rich.)
		3. Murrumbidgee Series, Taemas Stage <i>Spirifer yassensis</i> Limestone (I. A. Browne 1959)	
DEVONIAN OF SILURIAN		Limestone, Eurimbula	<i>Nowakia acuaria</i> (Rich.) aff. <i>Volynites russiensis</i> G. Ljasch.
SILURIAN	Upper	Calcareous shale, Louth bore Limestone, Cudal Manildra Formation (Joplin & others 1952) Siltstone, Cootamundra (Gill 1940)	aff. <i>Volynites russiensis</i> G. Ljasch.  <i>Tentaculites</i> sp. No. 4
	Wenlock	Hume Limestone, Yass (Brown & Sherrard 1952)	<i>Tentaculites ornatus</i> Sowerby

*ornatus* described by G. Ljaschenko (1958b) from the Upper Ludlow of Western Russia is considerably larger.

aff. *Volynites russiensis* G. Ljasch. has been determined in New South Wales in a bore core at Louth, in the Manildra Formation of the Silurian near Cudal and also twenty miles to the N. at two localities in the Par. of Eurimbula. *Volynites* is listed (Fisher 1962) as occurring in the Lower Devonian and Upper Silurian.

*Nowakia* aff. *acuaria* (Richter) accompanies aff. *V. russiensis* in limestone at Portion 26, Par. Eurimbula. *N. acuaria* is characteristic of the Lower Devonian in Bohemia and it also rarely occurs in the uppermost Silurian (Bouček 1964). Tröger (1959) and Zagora (1962) recorded it from Upper Graptolite Slates (Lochkovian) and from the Tentaculites Nodular Limestone (Sicgenian and Lower Emsian) of Thuringia.

The Garra Formation of the Devonian at Macquarie Park, Wellington, contains *Tentaculites chapmani* n. sp. and *Nowakia* aff. *acuaria* (Rich.). These two species have also been found together in the *Spirifer yassensis* limestone from the Taemas Stage of the Murrumbidgee Series of the Devonian. They both occur also in limestone at Ravine on the Yarrangobilly River near Upper Lob's Holc. As stated

earlier, according to Bouček (1964), *N. acuaria* (Rich.) is not found above the Lower Devonian in Czechoslovakia.

Tentaculitids examined up to the present from rocks of the Middle and Upper Devonian from N.S.W. are all casts and empty moulds and therefore cannot be specifically identified.

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### Explanation of Plates

#### PLATE 37

- Fig. 1—*Tentaculites chapmani* n. sp. Ravine, Lob's Hole, Yarrangobilly R. Longitudinal section showing annulations, riblets, canals, layering of wall, internal surface of wall. Aust. Mus. No. F43436.  $\times 50$ .
- Fig. 2—*Tentaculites ornatus* Sowerby. Hatton's Corner, Port. 7, Par. Hume, Yass. Longitudinal section showing rounded outline of annulations, layering, canals, smaller shells inside larger. Aust. Mus. No. F15838.  $\times 40$ .
- Fig. 3—*Tentaculites chapmani* n. sp. Port. 208, Par. Warroo, near Taemas Bridge, Yass. Longitudinal section showing layering, internal surface of wall. Syd. Uni. Geol. Coll. No. 5892.  $\times 30$ .

#### PLATE 38

- Fig. 4—*Tentaculites chapmani* n. sp. Port. 103, Par. Ponto, near Macquarie R., Wellington. Longitudinal section showing septa. Syd. Uni. Geol. Coll. No. 5896.  $\times 10$ .
- Fig. 5—*Tentaculites chapmani* n. sp. Holmes Station Paddock, Wellington, showing external surface. No. F688, Mining Museum, Sydney.  $\times 8$ .
- Fig. 6—Same as Fig. 4. Longitudinal section showing regular arrangement of annulations.  $\times 10$ .
- Fig. 7—Same as Fig. 1. Longitudinal section through tip of shell. Aust. Mus. No. F51893.  $\times 25$ .
- Fig. 8—aff. *Volynites russiensis* G. Ljasch. Port. 53, Par. Eurimbula about 35 miles NNW. Orange. Longitudinal section showing three sizes of annulations, septa. Transverse sections on same plane. Syd. Uni. Geol. Coll. No. 5895.  $\times 10$ .
- Fig. 9—aff. *V. russiensis* G. Ljasch. Port. 3, Par. Cudal, about 25 miles W. of Orange. Longitudinal section showing varying sizes of annulations and stepped character of internal surface of wall. Syd. Uni. Geol. Coll. No. 5890.  $\times 18$ .
- Fig. 10—*Tentaculites* sp. No. 1. ? Cavan, near Taemas Bridge, Yass. External surface. Syd. Uni. Geol. Coll. No. 5891.  $\times 4$ .
- Fig. 11—Same as Fig. 10. Longitudinal section showing thickness of wall, internal surface, riblets on annulations and inter-annular areas.  $\times 35$ .
- Fig. 12—*Tentaculites chapmani* n. sp. Port. 208, Par. Warroo. Transverse section. Syd. Uni. Geol. Coll. No. 5892.  $\times 30$ .
- Fig. 13—aff. *Volynites russiensis* G. Ljasch. and *Nowakia* aff. *acuarina* (Richter) on same slab. Port. 26, Par. Eurimbula. Syd. Uni. Geol. Coll. No. 5893.  $\times 15$ .
- Fig. 14—*Nowakia* aff. *acuarina* (Richter). Port. 26, Par. Eurimbula. Longitudinal section showing thinness of wall, rippling swellings and contractions. Syd. Uni. Geol. Coll. No. 5893.  $\times 18$ .
- Fig. 15—*Nowakia* aff. *acuarina* (Richter). Port. 65, Par. Taemas (Shearsby's Wall-paper). Longitudinal section. Syd. Uni. Geol. Coll. No. 5894.  $\times 25$ .



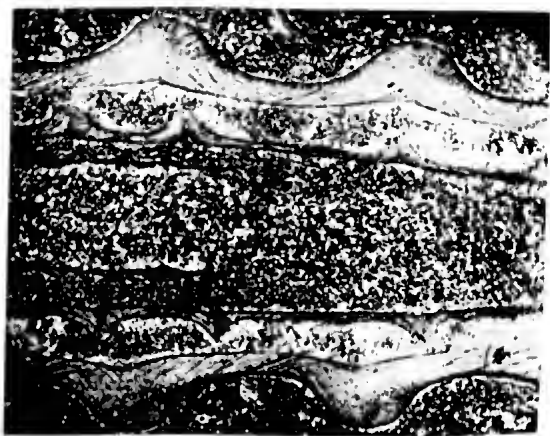




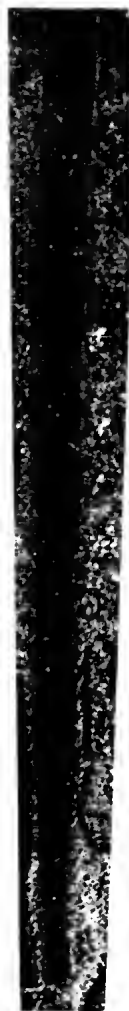
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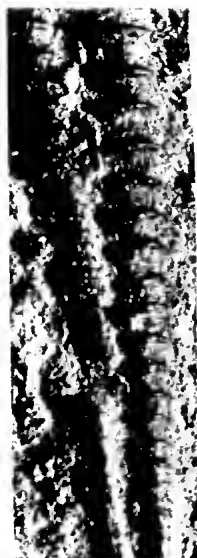
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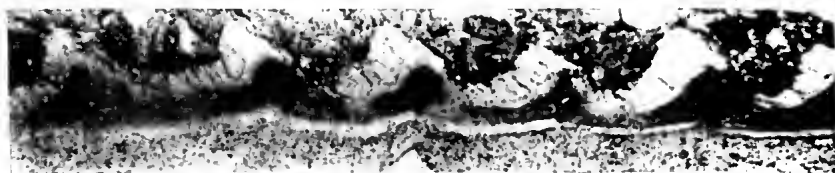
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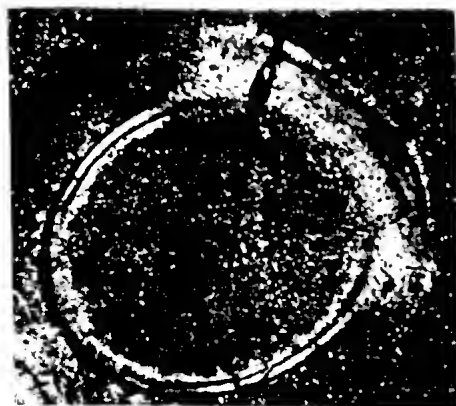
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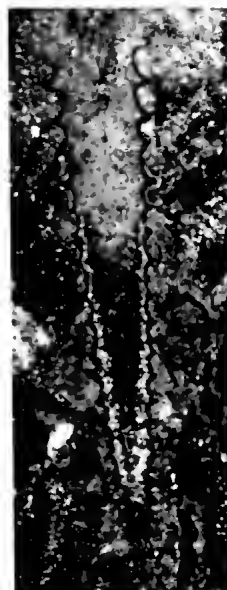
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## SOME MICROPLANKTON FROM THE PALEOCENE RIVERNOOK BED, VICTORIA

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### Abstract

Four new species of microplankton are described and twelve previously described species are recorded from a sample taken from the base of the Rivernook Bed of the Dilwyn Clay, Victoria. Brief mention is made of a few of the pollen and spore types present.

### Introduction

By D. J. TAYLOR

In this paper, Dr Isabel Cookson and Professor A. Eisenack are describing the microplankton content of a sample from the base of the Rivernook Bed of the Dilwyn Clay from the Pebble Point to Princetown Coastal section of Baker (1953). The sample was collected from 20 ft below the Upper Paleocene 'Rivernook foraminiferal fauna' of McGowran (1965). The base of the Rivernook Bed is mainly dark grey carbonaceous pyritic siltstone with some lenses of light green (grey on dehydration) micaceous, glauconitic clay. This green clay contained 75 per cent planktonics in a total count of 500 foraminiferal specimens per 100 gms. As this is the highest planktonic foraminiferal percentage in the Victorian Paleocene, I submitted this sample for microplankton examination.

McGowran (l.c.) considered his 'Rivernook foraminiferal fauna' to be correlative with the *Globorotalia pseudomenardii* subzone of the Tethyan belt and thus of Upper Paleocene age. McGowran's fauna contained *Globorotalia aequa* Cushman & Renz, without the older related species *G. angulata* (White) and *G. apantesma* Loeblich & Tappan. The basal Rivernook 'green clay' contains a planktonic fauna which includes the three species *G. aequa*, *G. angulata* and *G. apantesma*, implying that the fauna is distinct and older than McGowran's sample. I have described this 'green clay' fauna in manuscript and consider it to be near the top of the *Globorotalia pusilla pusilla*-*G. angulata* Zone of the Tethyan belt; thus on the Middle/Upper Paleocene boundary.

Harris (1965) has described and discussed the microfloral content of the Rivernook Bed, but his sample (S212) was from the same position as McGowran's (1965) foraminiferal sample. Harris placed his Rivernook sample within his *Triorites edwardsii*-*Duplopollis orthoteichus* Concurrent Range Zone: an overlapping biostratigraphic interval between the *T. edwardsii* Zone of the underlying Middle Paleocene Pebble Point Formation and the overlying Upper Paleocene *D. orthoteichus* Zone of the main part of the Dilwyn Clay.

Cookson (1965b) and Cookson & Eisenack (1965e) have described microplankton from the underlying Pebble Point Formation. Deflandre & Cookson (1955) have described microplankton from the overlying Princetown Member of the Dilwyn Clay (then considered Lower Eocene—now Upper Paleocene).

**Systematic Descriptions\***

Class DINOPHYCEAE

Family DEFLANDREACEAE Eisenack

Genus **Deflandrea** Eisenack 1938**Deflandrea obliquipes** Deflandre & Cookson

(Pl. 39, fig. 9-10, P25949)

*Deflandrea dartmooria* Cookson & Eisenack 1965b, p. 133, Pl. 16, fig. 2.

COMMENT: Specimens referable to *D. obliquipes*, previously recorded from two Victorian Paleocene deposits, namely the Pebble Point Formation and the Upper portion of the Dilwyn Clay, occur sparingly in the Rivernook sample. They approximate closely in shape, size-range, the inconspicuousness of the girdle, shape of archeopyle and the faintly granular ornamentation of both shell and capsule to the examples on which the species was based.

DIMENSIONS: Overall length 109-130  $\mu$ , breadth 62-74  $\mu$ .**Deflandrea dartmooria** Cookson & Eisenack

(Pl. 39, fig. 7, 8, P25948)

*Deflandrea dartmooria* Cookson & Eisenack 1965b, p. 133, Pl. 16, fig. 2.

COMMENT: A single specimen which is clearly referable to *D. dartmooria* from the Paleocene Dartmoor Formation, Victoria, has been recovered from the Rivernook sample. It approximates closely to the Dartmoor specimens in size, shape, the well-developed girdle, the hexagonal outline of the archeopyle, the presence, shape and position of the flagellum-pore and the surface ornamentation. Owing to the rather crushed condition of the specimen, the tabulation, though evident, is rather obscured.

DIMENSIONS: Overall length 130  $\mu$ , width 80  $\mu$ .**Deflandrea** sp.

(Pl. 39, fig. 6, P25947)

AGE AND OCCURRENCE: Paleocene. Rivernook Member of Dilwyn Clay, Victoria.

DESCRIPTION: Shell small, thin-walled, untabulated, with convex sides, a rather large straight-sided triangular to nearly cylindrical blunt apical horn and two rather short, widely-spaced divergent triangular antapical horns. Girdle relatively broad, shallow, approximately equatorial, longitudinal furrow relatively broad and shallow. Capsule large, filling the shell laterally. Surface of shell coarsely and closely granular, especially along the rims of the girdle.

DIMENSIONS: Figured specimen 90  $\times$  62  $\mu$ .

COMMENT: Only a few examples have been seen and all have been rather crushed.

Genus **Wetzeliella** Eisenack 1938**Wetzeliella hyperacantha** Cookson & Eisenack

(Pl. 40, fig. 11, P25955)

*Wetzeliella hyperacantha* Cookson & Eisenack 1965b, p. 134, Pl. 16, fig. 3-6.

\* The figured specimens are in the palaeontological collection of the National Museum of Victoria. Numbers prefaced by the letter P are registered numbers in that collection.

COMMENT: *W. hyperacantha* appears to be of rare occurrence in the Rivernook sample. The example figured herein comes within the range allowed for *W. hyperacantha* from the type locality, the Dartmoor Formation, Victoria.

Family HYSTRICHOSPHAERACEAE Evitt

Genus *Achomosphaera* Evitt 1963

*Achomosphaera ramulifera* (Deflandre)

(Pl. 41, fig. 2, P24771)

*Hystrichosphaeridium ramuliferum* Deflandre, 1937, p. 74-75, Pl. 15, fig. 5-6; Pl. 17, fig. 10.

*Hystrichosphaeridium ramuliferum* Deflandre; W. Wetzel 1952, p. 398, Pl. A, fig. 9.

*Hystrichosphaeridium ramuliferum* Deflandre; Gocht 1959, p. 71, Fig. 9.

*Hystrichosphaeridium ramuliferum* Deflandre; Gerlach 1961, p. 185, Pl. 2, fig. 3.

*Achomosphaera ramulifera* (Deflandre) Evitt 1963, p. 163, Fig. 4.

*Achomosphaera ramulifera* (Deflandre) Cookson & Hughes 1964, p. 45, Pl. 9, fig. 10.

COMMENT: Two specimens which appear to come within the range of *A. ramulifera* have been recovered from the Rivernook sample. On one side of the figured specimen, in the region of the girdle, a 'double' process somewhat similar to, but less pronounced than those of the type specimen, is present. Evitt (1963) has stated that 'undescribed species of the genus have been observed in strata ranging from Albian to Lower Tertiary in age'. On this account, therefore, in spite of some differences, the Victorian examples are being associated with the type species.

DIMENSIONS: Figured specimen—overall  $130 \times 120 \mu$ , shell 76-68  $\mu$ .

Family HYSTRICHOSPHAERIDIACEAE Evitt

Genus *Cordosphaeridium* Eisenack 1963

*Cordosphaeridium inodes* (Klumpff)

(Pl. 41, fig. 1, P25982)

*Hystrichosphaeridium inodes* Klumpff 1953, p. 311, Pl. 18, fig. 1-2.

*Hystrichosphaeridium inodes* Klumpff; Deflandre & Cookson 1955, p. 277, Pl. 8, fig. 7.

*Hystrichosphaeridium inodes* Klumpff; Gerlach 1961, p. 186, Pl. 28, fig. 4-5.

*Cordosphaeridium inodes* (Klumpff) Eisenack 1963, p. 118, Fig. 3.

*Cordosphaeridium inodes* (Klumpff) Cookson & Eisenack 1967, Pl. 3, fig. 12.

COMMENT: Several specimens referable to *C. inodes* have been recovered from the Rivernook sample. *C. inodes*, originally described and subsequently recorded from several European Lower Tertiary localities, has already been reported from three Australian deposits; the Princetown Member of the Dilwyn Clay and the Birregurra Bore between 760-761 ft and 959-960 ft in Victoria (Deflandre & Cookson 1955) both of Paleocene age (Harris 1965, p. 78) and a Lower Tertiary (probably Upper Paleocene) deposit near Strahan, Tasmania (Cookson & Eisenack 1967).

*Cordosphaeridium bipolare* Cookson & Eisenack

(Pl. 39, fig. 1-5, P24764-24768)

*Cordosphaeridium bipolare* Cookson & Eisenack 1965b, p. 135, Pl. 16, fig. 7-8.

COMMENT: The specimens from the Rivernook Formation herein associated with *C. bipolare*, whilst varying to a certain degree from those of the type locality, the Dartmoor Formation, Victoria, have been found to vary equally amongst themselves. However, the differences between the representatives of the two localities do not appear, on present knowledge, to be sufficient to justify specific separation.

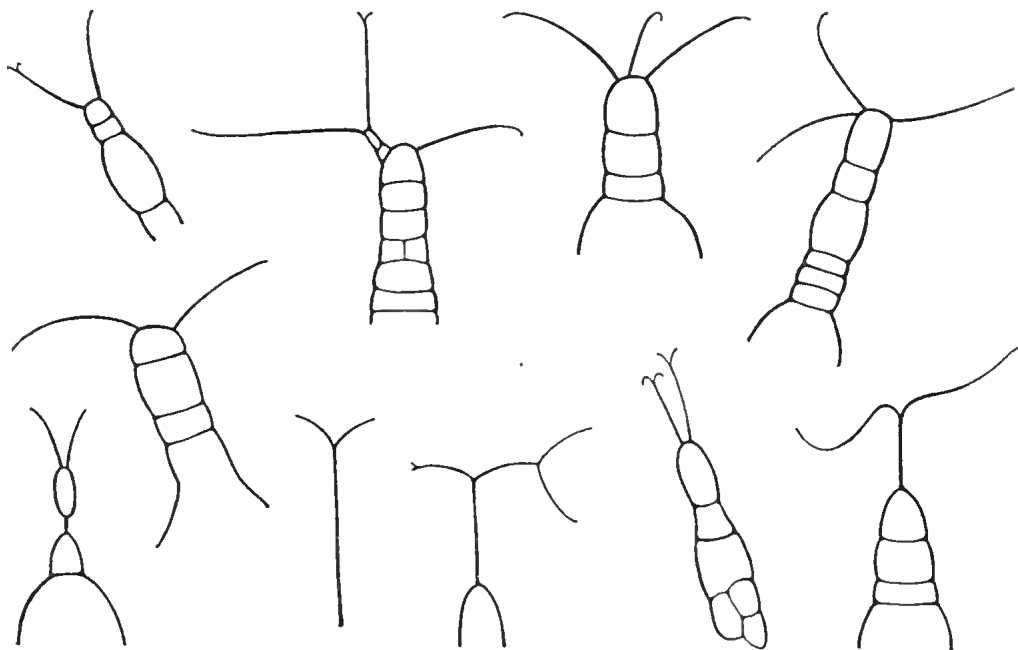


FIG. 1—*Baltisphaeridium septatum*. Sketches of appendages.  $\times$  c. 4000.

Such differences are: (1) In some of the Rivernook examples (Pl. 39, fig. 1-3) the small solid apical horn developed from the outer thin granular layer of the shell-wall is borne on a more or less prominent median apical projection of the smooth inner layer of the shell-wall—a feature not seen in any of the Dartmoor examples. (2) The number and width of the appendages in individual examples and in one and the same example from the Rivernook sample vary considerably. The appendages of the examples shown in fig. 1, 2 approach most closely in size and form those of the holotype and paratype from the Dartmoor Formation—those shown in fig. 4, 5, on the contrary, are much narrower, some almost thread-like, c.  $1\ \mu$  wide, and more sparsely developed. In the latter examples, both horns resemble those of the type.

The justification for placing the Rivernook specimens in *Cordosphaeridium* is the general flattening of the apices of the appendages and the presence in a few of the wider ones of fine longitudinal striations. Very occasionally as in *P. inodes* sub. sp. *gracilis* (Eisenaek 1954) a bifurcation is observable (Pl. 39, fig. 3).

#### Genus *Hystrichokolpoma* Klumpp

#### *Hystrichokolpoma rigaudae* Deflandre & Cookson

(Pl. 40, fig. 10, P25977)

*Hystrichokolpoma rigaudae* Deflandre & Cookson 1955, p. 279, Pl. 6, fig. 6, 10, 42.

*Hystrichokolpoma rigaudae* Deflandre & Cookson; Maier 1959, p. 311, Pl. 31, fig. 2.

*Hystrichokolpoma rigaudae* Deflandre & Cookson; Gerlach 1961, p. 183, Pl. 27, fig. 8, 9.

*Hystrichokolpoma rigaudae* Deflandre & Cookson; Rossignol 1964, p. 89, Pl. 2, fig. 5, Pl. 3, fig. 8.

*Hystrichokolpoma rigaudae* Deflandre & Cookson; Cookson & Eisenack 1965a, p. 129, Pl. 13, fig. 13, 14.

COMMENT: One well preserved, although incomplete specimen has been recovered from the Rivernook sample. The recorded time-range of this species in Victoria is from Upper Paleocene (Princetown Member of the Dilwyn Clay) to Upper Eocene (Browns Creek Clay). In Europe its recorded range is from Eocene (Maier 1959) to Pleistocene (Rossignol 1964).

Genus **Diphyes** Cookson

**Diphyes colligerum** (Deflandre & Cookson)

(Pl. 41, fig. 3, P25983)

non *Hystrichosphaeridium* sp. c. Cookson 1953, Pl. 2, fig. 29-30.

*Hystrichosphaeridium colligerum* Deflandre & Cookson 1955, p. 278, Pl. 7, fig. 3.

*Hystrichosphaeridium colligerum* Deflandre & Cookson; Cookson & Eisenack 1961, p. 44, Pl. 2, fig. 9.

*Baltisphaeridium colligerum* (Deflandre & Cookson) Downie & Sargeant 1963, p. 91.

*Diphyes colligerum* (Deflandre & Cookson) Cookson 1965a, p. 86, Pl. 9, fig. 1-12.

*Diphyes colligerum* (Deflandre & Cookson) Cookson & Eisenack 1967, p. 134, Pl. 17, fig. 7.

COMMENT: *D. colligerum* has been of regular occurrence in residues of the Rivernook sample. One feature of some of the examples, not previously observed, is the occurrence of a small median antapical projection of the wall of the shell (Pl. 41, fig. 3).

The known time-range of *D. colligerum* in Victoria is fairly long, from Upper Cretaceous (probably Senonian) to the Upper Eocene Browns Creek Greensand (Cookson 1965a). *D. colligerum* has also been recorded from a Paleocene deposit (Harris 1965, p. 100) in Western Australia (Cookson & Eisenack 1961) and recently from one near Strahan, Tasmania (Cookson & Eisenack 1967, p. 134).

Family AREOLIGERACEAE Evitt

Genus **Cyclonephelium** Deflandre & Cookson

emend Cookson & Eisenack 1962

**Cyclonephelium reticulosum** Gerlach

(Pl. 41, fig. 5-6, P25985-6)

*Cyclonephelium reticulosum* Gerlach 1961, p. 204, Pl. 29, fig. 2.

COMMENT: A number of specimens which appear referable to *Cyclonephelium reticulosum* Gerlach from German Oligocene deposits have been recovered from the Rivernook sample. They are also closely similar to the well-preserved specimen from the Paleocene Pebble Point Formation, earlier questionably compared with *C. reticulosum* (Cookson 1965b, Pl. 24, fig. 10). It now seems reasonably certain that this example and the ones from the Rivernook sample are specifically related and referable to the European species.

**Cyclonephelium retiintextum** Cookson 1965

(Pl. 41, fig. 4, P25984)

*Cyclonephelium retiintextum* Cookson 1965a, p. 88, Pl. 24, 16, fig. 8, 8a-9.

*Cyclonephelium retiintextum* Cookson 1965b, p. 137, Pl. 24, fig. 8-11.

COMMENT: Specimens referable to *C. retiintextum* have been fairly frequent in residues obtained from the Rivernook sample. They are distinguishable from those of *C. reticulosum* by the simple, looped and wide-meshed character of the network which is situated within the margin of the body. *C. retiintextum* originally based on two specimens obtained from Upper Cretaceous cuttings from a bore in south-western Victoria, was subsequently found in abundance in samples taken near the base of the Paleocene Pebble Point Formation in SW. Victoria (Cookson 1965b).

## Family Uncertain

Genus **Kenleyia** Cookson & Eisenack 1965**Kenleyia fimbriata** n. sp.

(Pl. 40, fig. 1-7; holotype, fig. 3, P24769)

AGE AND OCCURRENCE: Upper Paleocene. Rivernook Member of Dilwyn Clay, Victoria.

DESCRIPTION: Shell broadly oval, somewhat flattened, typically with a relatively short, solid, blunt or sharply-pointed apical and antapical horn and usually an indistinctly delimited girdle (Pl. 40, fig. 6). The surface is more or less clearly marked out into a few large, approximately circular areas by vertical lace-like fringes of varying widths. Usually these areas, which frequently are most clearly outlined on the dorsal surface to the right and left of the mid-line, pass over the lateral margins to the ventral surface. The archeopyle is rather large, precingular and hoof-shaped. The surface of the shell is finely and closely granular.

DIMENSIONS: Holotype—overall length c. 118  $\mu$ , overall breadth c. 104  $\mu$ ; shell c. 88  $\times$  80  $\mu$ . Range—overall length c. 100-120  $\mu$ , overall breadth c. 84-112  $\mu$ .

COMMENT: The association of the above-described type with the genus *Kenleyia* is based on a similarity as regards shape, the development of both apical and antapical horns, a large precingular archeopyle and to a lesser degree, the type of ornament.

In the latter respect *K. fimbriata* approaches most closely to *K. lophophora* Cookson & Eisenack (1965, 1967) from two Paleocene deposits, namely the Dartmoor Formation, Victoria and the one near Strahan, Tasmania. It differs from the great majority of specimens of *K. lophophora* in the fact that (1) the fibrils composing the external ornament are fused distally with the formation of lace-like membranes of varying widths and (2) that these expansions do not cover the whole shell, but merely delimit the large roughly circular areas into which the surface of the shell is more or less clearly divided.

As regards the type of ornament, it now seems that one of the figured specimens from the Dartmoor Formation ascribed to *K. lophophora* (Cookson & Eisenack 1965, Pl. 17, fig. 10) may be closer to, if not identical with *K. fimbriata*. However, in it the subdivision of the surface is not evident.

**Kenleyia pachycerata** Cookson & Eisenack

(Pl. 40, fig. 8, P25975)

*Kenleyia pachycerata* Cookson & Eisenack 1965, p. 136, Pl. 17, fig. 1-3.

COMMENT: A few specimens referable to *K. pachycerata* from the Paleocene Dartmoor Formation have been recovered from the Rivernook sample.

Genus **Thalassiphora** Eisenack & Goehlt 1960**Thalassiphora flammea** n. sp.

(Pl. 42, fig. 1-5; holotype, fig. 1, P24760)

AGE AND OCCURRENCE: Upper Paleocene. Rivernook Member of the Dilwyn Clay, Victoria.

DESCRIPTION: Shell approximately oval, rather thick-walled with a sub-apical archeopyle and a finely reticulate to more or less open lace-like wing.

DIMENSIONS: Holotype—shell c. 82  $\mu$  long, c. 72  $\mu$  broad, archeopyle c. 30  $\times$  24  $\mu$ ; wing c. 50  $\mu$  wide.



COMMENT: *T. flammea* agrees in general features with *T. velata* (Deflandre & Cookson 1955) from two Western Australian Lower Tertiary deposits (Cookson & Eisenack 1962). However, in *T. velata* the wing-like expansions are so faintly patterned as to give a general impression of smoothness and entirety, in contrast to the more coarsely dotted to finely open lacey appearance characteristic of *T. flammea*.

*T. flammea* differs from the type species *T. pelagica* (Eisenack 1954) from European Eocene deposits, in the absence of an antapical projection and type of wing structure. In the Victorian specimen shown in Pl. 42, fig. 4, at present associated with *T. flammea*, the wing, which is complete, is narrower ( $5\text{--}24\ \mu$  wide) and thicker and denser than those of the type and other examples from the Rivernook sample. An example, apparently closely related to *D. flammea* though with a still more open wing structure, is present in a preparation of a deposit in the Nelson Bore, SW. Victoria at 730 ft (P25978).

Group ACRITARCHA

Subgroup ACANTHOMORPHITAE

Genus **Baltisphaeridium**

**Baltisphaeridium liniferum** n. sp.

(Pl. 40, fig. 9, paratype, P25976; Pl. 41, fig. 7, 8; fig. 7, P25987;  
fig. 8, holotype, P25990)

AGE AND OCCURRENCE: Upper Paleocene. Rivernook Member of the Dilwyn Clay, Victoria.

DESCRIPTION: Shell slightly oval with a moderately thick, faintly granular to smooth wall, an apical archeopyle and a variable number of solid appendages of variable size and shape.

The appendages, which are generally solid throughout their length, bi- or trifurcate distally into short or longish thread-like branches, with pointed or bifurcate tips. The bases of the appendages, which occasionally may be hollow, are frequently broadened and root-like and characteristically connected with those of neighbouring appendages, by narrow straight or curved strands which, in some deeply stained examples, appear as lightish lines on the coloured surface (Pl. 40, fig. 9).

DIMENSIONS: Holotype—overall width *c.*  $108\ \mu$ ; shell *c.*  $67\ \mu$  long, *c.*  $75\ \mu$  broad; appendages *c.*  $16\text{--}30\ \mu$  long. Range—shell *c.*  $65\text{--}75\ \mu$  broad, appendages *c.*  $12\text{--}27\ \mu$  long, *c.*  $1\text{--}3\ \mu$  wide.

**Baltisphaeridium septatum** n. sp.

(Pl. 42, fig. 6-10; holotype, fig. 6, P25979; paratype, fig. 8, P25980); Fig. 1)

*Hystrichosphaera crassipellis* Deflandre & Cookson; Gerlach 1961, p. 177, Pl. 27, fig. 5; Fig. 16, 17, 23.

AGE AND OCCURRENCE: Upper Paleocene. Rivernook Member of Dilwyn Clay, Victoria.

DESCRIPTION: Shell spherical, thin-walled with a closely and rather coarsely, apparently granular surface and a variable number of radially arranged appendages which approximate in length to the radius of the shell. A 'marginal zone' often present, giving the impression that the shell is thick-walled, is, in fact, due to compression.

The appendages vary in size, shape and structure. The majority narrow somewhat from a broadened base and divide distally into two or three straight or curved tapering branches with closed, pointed or minutely bifurcate tips. The larger appendages are typically hollow and septate throughout (Pl. 42, fig. 9, 10; Fig. 1); in the finer to thread-like ones, on the contrary (Pl. 42, fig. 8) the degree of septation is often difficult to determine and their distal portions, at least, appear to be solid. A few of the appendages are unbranched. A pylome has been seen in a few specimens (Pl. 42, fig. 7).

**DIMENSIONS:** Holotype—overall diameter c. 80  $\mu$ ; diameter of shell c. 57  $\mu$ , appendages c. 10-18  $\mu$  long. Range—shell diameter c. 42-58  $\mu$ .

**COMMENT:** At first sight the shape and wall structure of the shell of *Baltisphaeridium septatum* suggested a possible affinity with *Hystrichosphaera crassipellis* (Deflandre & Cookson 1955). However a re-examination of the holotype of *H. crassipellis* has shown that, although in it no trace of the tabulation characteristic of the genus *Hystrichosphaera* exists, the two largest and best preserved of the appendages are open distally, non-septate, and have a granular surface (Pl. 42, fig. 11, 12), all characters which clearly separate it from *Baltisphaeridium septatum*.

One of us (A.E.) has had the opportunity of re-examining in the light of the present investigation, the specimens from the Oligocene and Miocene deposits of West Germany upon which Gerlach (1961) based her record of the species *Hystrichosphaera crassipellis* mentioned above. This reinvestigation has shown that the shells of the German specimens are completely untabulated, that the appendages are closed distally and that some, at least, are hollow and septate, not perforated as Gerlach states, all characters suggestive of a close relationship with *B. septatum* rather than with *H. crassipellis* as established by Deflandre & Cookson. The actual wall structure of *B. septatum* is very difficult to determine and it seems quite likely that, were sections to be obtained, the surface pattern would prove to be reticulate rather than granular as suggested above.

#### Subgroup SPHAEROMORPHITAE

#### Genus *Leiosphaeridia* Eisenack 1958

#### *Leiosphaeridia trematophora* Cookson & Eisenack

(Pl. 40, fig. 12, P25956)

*Leiosphaeridia trematophora* Cookson & Eisenack 1967, p. 136, Pl. 19, fig. 13.

**COMMENT:** The single specimen recovered from the Rivernook sample is comparable with those from a Paleocene deposit, near Strahan, Tasmania (Cookson & Eisenack 1967) and an Upper Eocene deposit at Browns Creek, Victoria (Cookson & Eisenack 1965).

#### Pollen and Spores (I.C.C.)

Although no attempt is being made to give a detailed record of the pollen and spore content of the Rivernook sample under consideration, mention of the occurrence of two readily recognizable types of some stratigraphical interest seems desirable. These are the pollen types *Proteacidites pachypolus* Cookson & Pike 1954 and *Monosulcites prominatus* McIntyre 1965. The occurrence of four remanié forms will be noted.

*Proteacidites pachypolus* (Pl. 41, fig. 9) whilst not abundant, has been regularly present in preparations of the Rivernook sample. This well-characterized type has been recorded by Cookson & Pike (1954) from several Australian Lower Tertiary

deposits and by Harris (1965) from the Upper Paleocene Princetown Member of the Dilwyn Clay which directly overlies the Rivernook Member from which the sample studied was taken.

*Monosulcites prominatus* (Pl. 4, fig. 10), a fossil pollen type structurally similar to pollen of the Palm, *Lepidocaryum gracile* (cf. Erdtman 1952, p. 305, Fig. 177B), was originally described and recorded by McIntyre (1965) from Paleocene to Middle Eocene deposits in New Zealand. Specimens closely similar to *M. prominatus* are now known from three Australian Paleocene deposits, namely the Dartmoor Formation (recorded from thence under the name *Baltisphaeridium taylori* by Cookson & Eisenack 1965b), the Rivernook sample under consideration (Pl. 41, fig. 10) and a deposit of probable Upper Paleocene age near Strahan, Tasmania (Cookson & Eisenack 1967, Pl. 18, fig. 8-12).

Of the remaining spore types observed in residues of the Rivernook sample, a species of the Permian genus *Nuskoisporites* Potonic & Klaus is the most conspicuous. This form has been previously recorded from Cretaceous and several Lower Tertiary deposits in south-eastern Australia (Cookson 1955) and from the Princetown Member of the Dilwyn Clay (Harris 1965).

One specimen which agrees with *Potoniesporites* sp. remanié in the Princetown Member of the Dilwyn Clay (Harris 1965, Pl. 2, fig. 1) has been recovered from the Rivernook sample.

Two readily recognizable Cretaceous sporotypes which may possibly be derived forms, namely *Pilosporites notensis* Cookson & Dettmann and *Rousisporites reticulatus* Pocock (cf. Dettmann 1963) have been present in residues of the Rivernook sample.

### Conclusion

It is noted in the introduction that the basal Rivernook sample examined is probably within Harris's (1965) *Triorites edwardsii-Duplopollis orthoteichus* Concurrent Range Zone. However, although neither of the sporomorphs *Triorites edwardsii* and *Duplopollis orthoteichus* was observed, the presence of *Proteacidites pachypolus* suggests Harris's *D. orthoteichus* Zone which is high in the sequence and equivalent to Microflora C of Cookson (1954).

### Acknowledgements

We wish to thank Mr D. J. Taylor, M.Sc., for providing the sample upon which this paper is based and Dr S. L. Duigan for preparing Fig. 1 and confirming our conclusions regarding the structure of the appendages of *Baltisphaeridium septatum*.

One of us (I.C.C.) has had financial assistance from the Commonwealth Scientific and Industrial Research Organization.

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### Explanation of Plates

#### PLATE 39

- Fig. 1-5—*Cordosphaeridium bipolare* Cookson & Eisenack. 1, 2, 5  $\times$  c. 450, 3, 4  $\times$  c. 600. Hypotypes (P24764-24768).
- Fig. 6—*Deflandrea* sp.  $\times$  c. 600 (P25947).
- Fig. 7, 8—*Deflandrea dartmooria* Cookson & Eisenack. Ventral and dorsal surfaces of the same specimen  $\times$  c. 450 (P25948).
- Fig. 9, 10—*Deflandrea obliquipes* Deflandre & Cookson. 9  $\times$  c. 450, 10  $\times$  c. 400. (P25949.)

## PLATE 40

- Fig. 1-7—*Kenleyia fimbriata* n. sp. 1-6  $\times$  c. 450; 3 holotype (P24769); paratypes, 1 (P25970), 2 (P25971), 4 (P24770), 5 (P25972), 6 (P25973), 7  $\times$  c. 430 (P25974).  
 Fig. 8—*Kenleyia pachycerata* Cookson & Eisenack  $\times$  c. 450 (P25975).  
 Fig. 9—*Baltisphaeridium liniferum* n. sp.; paratype  $\times$  c. 450 (P25976).  
 Fig. 10—*Hystriehokolpoma rigaudae* Deflandre & Cookson  $\times$  c. 450 (P25977).  
 Fig. 11—*Wetzelietta hyperacantha* Cookson & Eisenack  $\times$  c. 550 (P25955).  
 Fig. 12—*Leiosphaeridia trematophora* Cookson & Eisenack  $\times$  c. 400 (P25956).

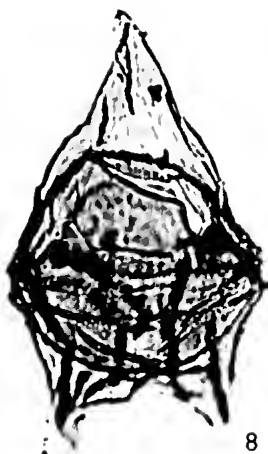
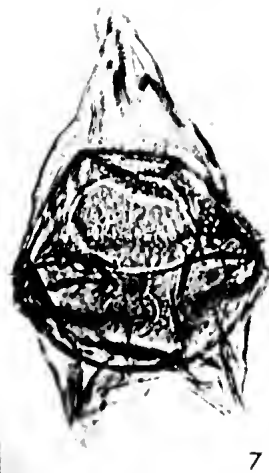
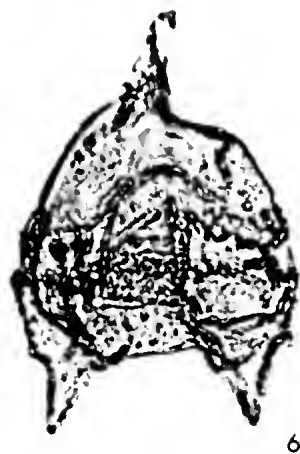
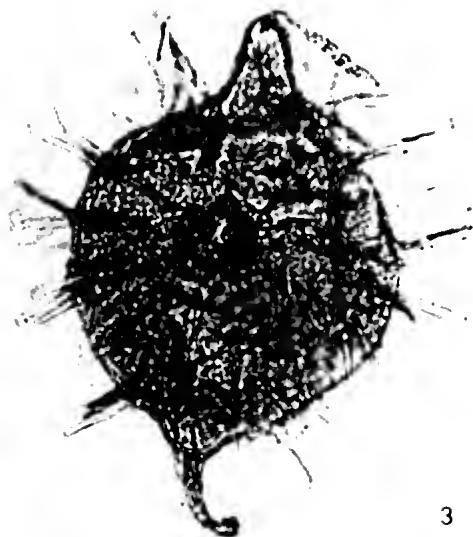
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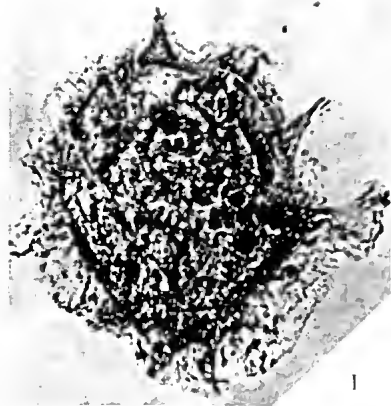
- Fig. 1—*Cordosphaeridium inodes* Eisenack & Gocht  $\times$  c. 430 (P25982).  
 Fig. 2—*Achomosphaera ramulifera* (Deflandre)  $\times$  c. 430 (P24771).  
 Fig. 3—*Diphyes colligerum* (Deflandre & Cookson)  $\times$  c. 650 (P25983).  
 Fig. 4—*Cyclonephelium retiintextum* Cookson  $\times$  c. 450 (P25984).  
 Fig. 5, 6—*Cyclonephelium reticulosum* Gerlach  $\times$  c. 450 (P25985-6).  
 Fig. 7, 8—*Baltisphaeridium liniferum* n. sp., 7 (P25987)  $\times$  c. 450, 8 holotype  $\times$  c. 500 (P25990).  
 Fig. 9—*Proteacidites pachypolus* Cookson & Pike  $\times$  c. 450.  
 Fig. 10—*Monosulcites prominatus* McIntyre  $\times$  c. 450.  
 Fig. 11—*Nuskoisporites* sp.  $\times$  c. 330.

## PLATE 42

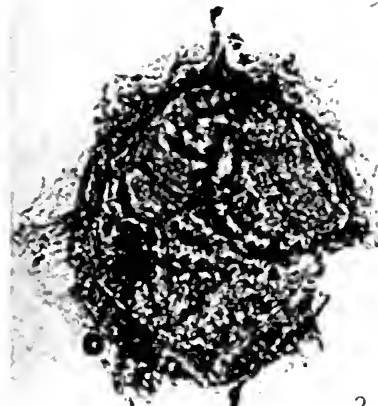
- Fig. 1-5—*Thalassiphora flammea* n. sp. 1, holotype (P24760)  $\times$  c. 450; 2-5  $\times$  c. 450. Fig. 5 paratype (P24761).  
 Fig. 6-10—*Baltisphaeridium septatum* n. sp. 6, holotype (P25979)  $\times$  c. 600, 7, showing archeopyle  $\times$  c. 600; 8, paratype (P25980)  $\times$  c. 1000; 9, 10, appendages  $\times$  c. 1200 (P25981).  
 Fig. 11-12—*Hystriehosphaera crassipellis* Deflandre & Cookson, two appendages of holotype  $\times$  c. 1200.



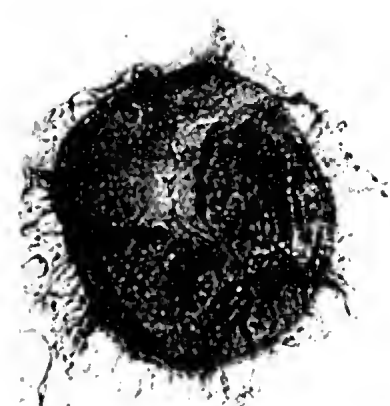




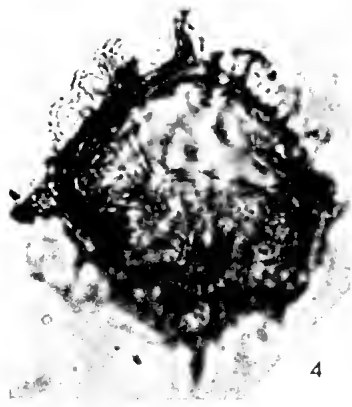
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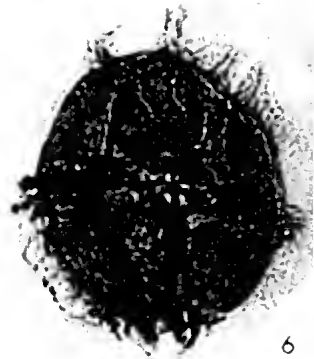
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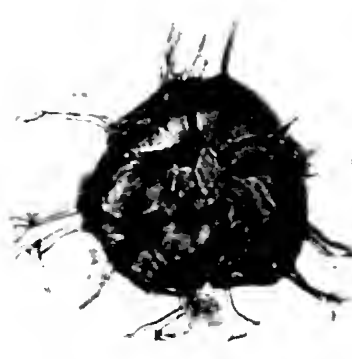
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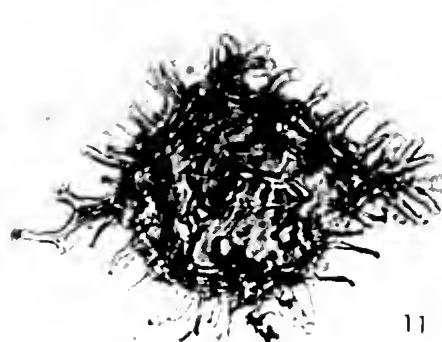
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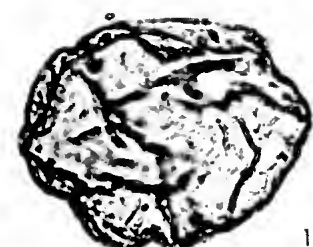
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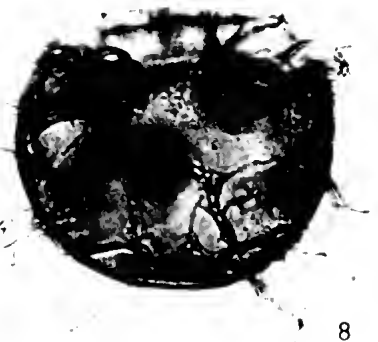
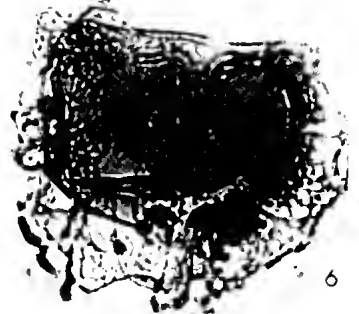
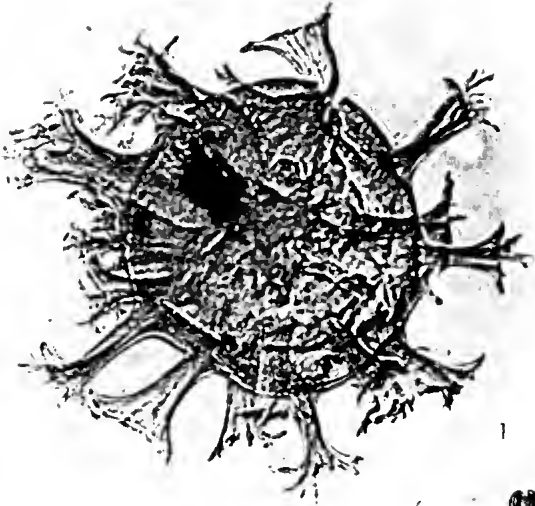


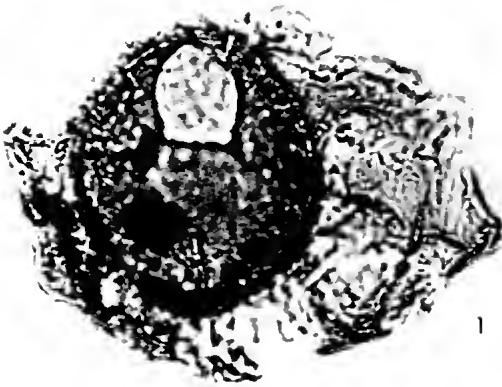
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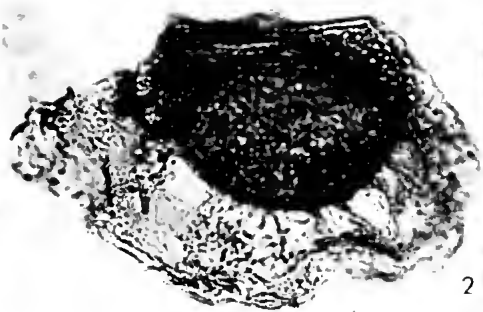
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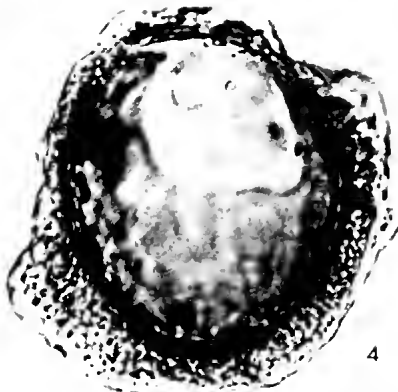
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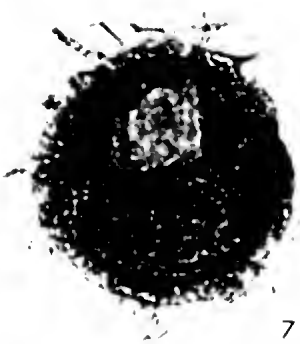
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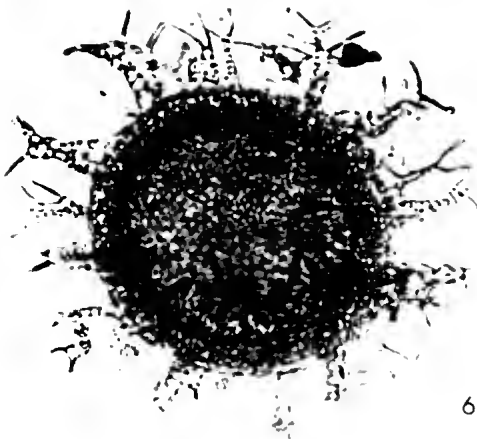
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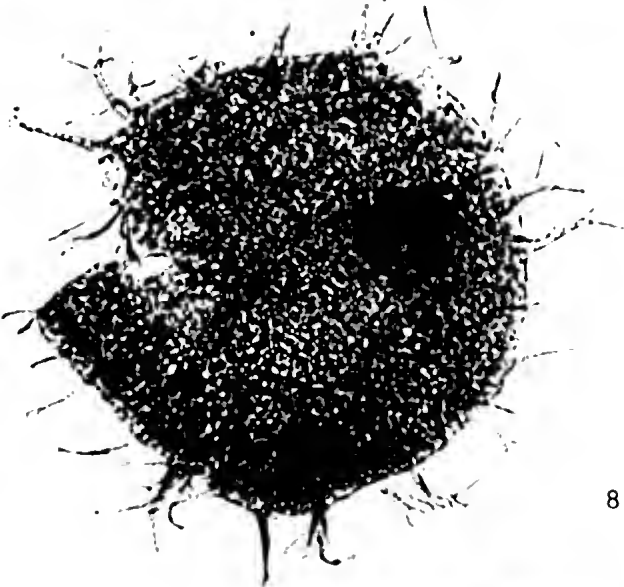
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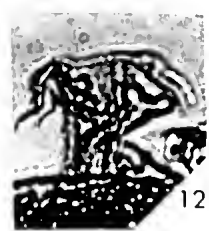
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THE GENERA *PARACALAIS* GEN. NOV. AND *AUSTROCALAIS*  
GEN. NOV. (COLEOPTERA : ELATERIDAE)

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**Abstract**

The systematic positions of the genera *Alaus* Eschscholtz and *Calais* Castelnau are discussed. They are regarded as two distinct genera, and criteria for separating them are cited.

Two new, closely-related genera are erected: *G. Paracalais* Neboiss, and *G. Austrocalais* Neboiss.

Species previously referred, in Australia, to the genus *Alaus* are transferred to *G. Paracalais*; two are synonymized, and descriptions given of 6 new species attributed to this genus.

*G. Austrocalais* is described, with 2 new species.

**Introduction**

The species of the genus *Alaus* s. lato, has been discussed by various authors, with wide disagreement as to their grouping. A full resolution of these disagreements would require a world-wide revision of all described species of this genus. The Australian species of this genus is subject for detailed discussion in the present publication. However, the generic position of Australian species must be considered in relation to the American and African groups. The complexity of the problem is indicated by the following historical and taxonomic notes, and at the conclusion a key for separating the generic groups is given.

The genus *Alaus* was first described by Eschscholtz (1829) to include two North American species—*oculatus* Linnaeus and *myops* Fabricius. Hyslop (1921) formally designated *oculatus* as the type species for the genus *Alaus*. He quoted Fabricius as the author of the species but also included a note saying that Fabricius and subsequent authors refer to Linnaeus as the actual author of *oculatus*.

Laporte de Castelnau (1836—no exact date of this publication is known and therefore assumed to have appeared at the end of December) published the name *Calais* as a new generic name to include two African species—*senegalensis* and *sinuosicollis*, and one from the West Indies—*tricolor*.

The name *Calais* had appeared in zoological literature twice before. First it was used by Rafinesque (1815) as a generic name for a group of Crustacea, but as no species were included, the name had no standing in zoological nomenclature, and can be regarded as nom. nudum. In the second instance, *Calais* was used by Boisduval (April 1836: 584-585) claiming that it was a synonym of the genus *Idmais* (Order Lepidoptera). However, the short paragraph on p. 585 does not constitute a description of *Calais*, and therefore the name again has no standing in the zoological nomenclature. This allows the name *Calais* as used by Laporte de Castelnau to be retained as a valid generic name in the family Elateridae.

Candèze (1857) placed the two original African species of *Calais*—*senegalensis* and *sinuosicollis* in the genus *Alaus*; but recognized the genus *Calais* as valid for a group of five West Indian and American species—*tricolor*, *nobilis*, *patricia*, *glauca* and *ophthalmica*.

The same author (1874) considered *Calais* to be synonymous with *Alaus*, and listed a total of 79 species under the latter name from America, Africa, Asia and

Australia. He also suppressed *senegalensis* Cast. to synonymy under *excavatus* Fab.

Schwarz (1906), regarding *Calais* as a sub-genus of *Alaus*, included 14 American species. This group contained four of Candèze's species listed above; however, it excluded the fifth, *ophthalmica* which was transferred to genus *Meroplinthus*.

Hyslop (1921) selected and formally designated *senegalensis* Cast. as type species for the genus *Calais*, but apparently overlooked that Candèze suppressed this species to synonymy of *excavatus* Fabricius. He reversed the arrangement of Schwarz, since the name *Calais* was ascribed to the African species and the name *Alaus* to the American species.

Schenkling (1925) followed the arrangement suggested by Schwarz, treated *Calais* as a sub-genus of *Alaus* and placed 16 American species in it including *oculatus* Linn., the type species of the genus *Alaus* as designated by Hyslop.

The present author suggests the segregation of American, African and Australian species into generically distinct groups—genera *Alaus* Eschscholtz, *Calais* Castelnau and *Paracalais* gen. nov. respectively.

The first genus under consideration is therefore *Alaus* Eschsch. s. stricto, with type species *oculatus* Linn. Besides the type species, the present author was able to examine only *myops* Fab. in this genus.

The second genus discussed is *Calais* Castelnau non Boisduval (1836) with type species *excavatus* Fab. (= *senegalensis* Cast.).

All of the Australian species previously described under *Alaus* belong to the new genus *Paracalais*, whereas two new species are sufficiently different to be included in another new genus—*Austrocalais*.

Detailed locality and collection data are given for new species only. The collections from which specimens were examined are listed hereunder, together with abbreviations used in text.

AM	Australian Museum, Sydney
BM	British Museum (Natural History), London
CALIF	Californian Academy of Sciences, San Francisco
CSIRO	Australian National Insect Collection, CSIRO, Canberra
DEI	Deutsches Entomologisches Institut, Berlin
ETS	Private collection of Mr E. T. Smith, Melbourne
FH	Private collection of Mr F. Hallgarten, Melbourne
FTF	Private collection of Mr F. T. Fricke, Sydney
IRSNB	Institut Royal des Sciences Naturelles de Belgique, Brussels
JA	Private collection of Mr J. Armstrong, Nyngan, N.S.W.
JS	Private collection of Mr J. Salkild, Sydney
LG	Private collection of Mr G. L. Gooding, Warragul, Vic.
MACL	Macleay Museum, Sydney
MGF	Museum G. Frey, Tutzing bei München
MHN	Museum National d'Histoire Naturelle, Paris
NM	National Museum of Victoria, Melbourne
NSWDA	New South Wales Department of Agriculture, Rydlemere, N.S.W.
QDPI	Queensland Department of Primary Industry, Brisbane
QM	Queensland Museum, Brisbane
QU	Queensland University, Brisbane
SAM	South Australian Museum, Adelaide

### Differentiation of Genera

The genera may be separated as follows:

#### *Alaus* s. stricto (American species)

Abdomen in both sexes terminates with evenly rounded 5th sternite; female without modified hairs along the posterior margin of the 5th sternite; scutellum slightly

convex or flat, evenly sloping anteriorly; a pair of large 'eye' spots on pronotum; the paired horseshoe-like chitinous collars on bursa copulatrix rather thin, one side being much shorter than the other (Fig. 1).

TYPE: *Alaus oculatus* L. (designated by Hyslop 1921).

#### **Calais** (Africa and Asia)

Males with 5th sternite rounded, females with 5th sternite squared off posteriorly and covered with modified (clavate) hairs along the posterior margin; scutellum short, raised and abruptly depressed anteriorly; base of elytra raised; paired horseshoe-like chitinous collars robust, both sides about equal length (Fig. 3); aedeagus with apices of the lateral lobes somewhat sculptured, apical hooks distinct (Fig. 2), the entire basal sections elongate.

TYPE: *Calais excavatus* Fab. (Pl. 46, fig. 24) (= *senegalensis* Cast.) (designated by Hyslop 1921).

#### **Paracalais** (gen. nov.) (Australia, New Guinea, Malayan Archipelago)

Formation of 5th abdominal sternite in male and female similar to that in genus *Calais*. The second and third antennal segments of approximately equal length, as in genus *Calais*. Scutellum flat, gradually sloping anteriorly; in majority of species the third interval more or less elevated to a short ridge or tubercle near the base; paired horseshoe-like chitinous collars moderately robust, one side distinctly shorter than other; aedeagus with lateral lobes not sculptured, apical hooks simple, acute; base short.

TYPE: *Paracalais suboculatus* (Candèze).

#### **Austrocalais** (gen. nov.) (Australia)

The 5th abdominal sternite in males truncate, 6th protruding and rounded. In females similar to that in genera *Calais* and *Paracalais*; third antennal segment at least twice as long as second; chitinous horseshoe-like collars on bursa copulatrix very broad, robust, with one side slightly shorter than the other; aedeagus with lateral lobes rounded at apex, apical hook obscure.

TYPE: *Austrocalais pogonodes* gen. et sp. n.

#### **Genus Paracalais** gen. nov.

Type species: *Paracalais suboculatus* (Candèze) comb. nov.

(Pl. 43, fig. 15)

The genus contains medium to large rather robust species. The majority of species also have a more or less distinct lateral mark, at about the middle of the sides of the elytra. The entire body is covered with dense whitish, yellowish or greyish scales which are intermingled with darker ones forming regular or irregular patterns.

DESCRIPTION: Legs moderately long, tarsi simple, segments 1-4 diminishing in length, 5th long, about as long as 2-4 together, densely pilose beneath; claws with one or two bristles.

Head gradually slopes forward, more or less depressed in the middle, not carinate in front. Antennae rather short, serrate; 1st segment long, thickened and slightly curved; 2nd and 3rd segments very short—2nd almost globular, 3rd as long or slightly longer than 2nd, but combined length not exceeding the length of 4th

segment; segments 4-10 flattened laterally and diminishing in length; 11th segment oval or elongate, more or less recessed near the apex.

Pronotum moderately to strongly convex, lateral margins usually depressed, posterior angles short, carinate. Prosternum narrowed posteriorly, with sutures almost straight or only slightly curved; antennal grooves present, but short.

Scutellum elongate, pentagonal, flat or slightly depressed in the middle and gradually sloping anteriorly. Elytra transversely convex, elongate with apices varying from conjointly rounded to individually emarginate or mucronate. Striae

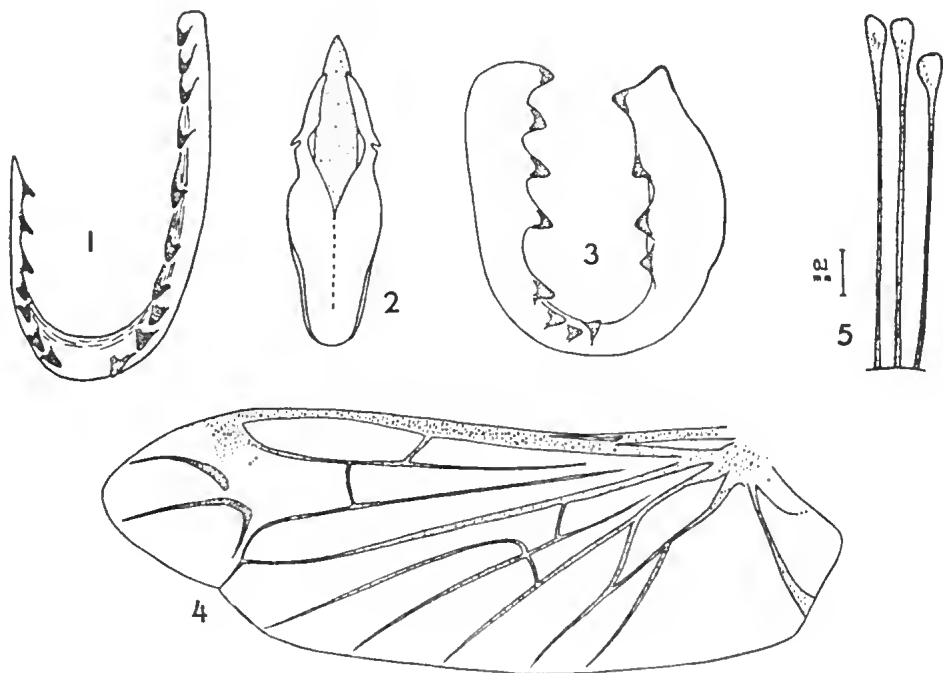


FIG. 1-5—*Alaus oculatus* (L.)—1—chitinous collar of bursa copulatrix; 2-3—*Calais excavatus* (Fab.); 2—aedeagus; 3—chitinous collar of bursa copulatrix; 4-5—*Paracalais prosectus* (Cand.); 4—wing venation; 5—clavate hairs of 5th sternite.

shallow, sometimes indicated by a row of small punctures only; intervals flat or slightly convex, usually finely punctate. The 3rd interval at the base usually raised to form an elevated ridge or tubercle. Wing venation as shown in Fig. 4.

The last visible (5th) abdominal sternite in males reaches almost to the apex of elytra, evenly rounded; in females somewhat squared off and densely covered with specialized (clavate) hairs (Fig. 5) along the posterior margin. A pocket formed by 6th and 7th sternites, at the end of which open the anus, always filled with humus.

The male genitalia slender with lateral lobes of the aedeagus pointed, and apical hooks distinct but short. Internal genitalia of females include a pair of horseshoe-like chitinous collars on bursa copulatrix near and around the entry of colleterial duct.

REMARKS: The naming of Australian *Paracalais* species has been very erratic so that the names attached to some specimens are very misleading.

Before this revision 18 specific names were found to be published and referred in literature to the Australian fauna; one of them, *Alaus mixtus*, was not listed in 'The Check List of Australian Elateridae' (Neboiss 1956: 15-17). This name used by Froggatt (1927, 48) without indication of author or reference, appears to be an unpublished name and as such should be regarded as *nomen nudum*. Further problems arise from Froggatt's papers (1925, 1926 and 1927) with his references to '*Alaus prosectus*'. The figures and descriptions should be referred to *P. gibboni*. While there is doubt about his identification of *P. sericeus* (published as *Alaus sericus*), the identity of *P. macleayi* appears to be correct, as there is a figure published which indicates sufficient details for its recognition.

Examination of Australian material revealed two very distinct, undescribed species, both known from Northern Queensland. Their morphological differences were regarded as sufficient to warrant their separation at generic level and a new genus *Austrocalais* is proposed for them. Among the others were species which appeared foreign to the Australian fauna. One specimen, a male from the Australian Museum, Sydney (K32869) labelled 'N. Australia id. by H. J. Carter as *Alaus macleayi*' is *Calais speciosus* Linné, a well-known spectacular species from Ceylon. Of two other large species one, which is labelled 'N. Australia' from the Australian Museum (K32868) id. by H. J. Carter as *Alaus gibboni* is actually *Alaus sordidus* Westwood, another species from Ceylon and India, while the second, from the National Museum of Victoria labelled 'Queensland', is *Alaus vollenhoveni* Candèze and appears to be unknowingly mixed in among Australian specimens.

The material received from Deutsches Entomologisches Institut, Berlin contained, amongst others, a single specimen identified by Schwarz as *Alaus regalis* and labelled 'Australia'. This species is known to occur in Borneo, and until such time as more material from definite Australian localities is available, should not be regarded as a member of the Australian fauna. The type specimen of *Alaus rectangularis* Schwarz from the same institution showed all characteristics of the genus *Paracalais*, and therefore it is ascribed to this genus. The locality for this species is Larat Island (7° 09'S 131° 45'E) some 450 km N. of Darwin. A number of species recently described in the genus *Alaus* from New Guinea by Zwaluwenburg (1963) also appear to have *Paracalais* elements among them. These would require consideration simultaneously with other *Alaus* species from the Indo-Malayan region.

The material examined also contains a number of specimens which almost certainly belong to new species, but due to their very small number (often only a single specimen) they are not described.

All available information for larvae has been published by Froggatt (1926 and 1927). Most of the given details refer to larvae collected by Froggatt himself and bred to adult stage. Erroneously he identified them as *Alaus prosectus*. The specimens to which Froggatt refers in his publications were available for study from the British Museum Collection, and have now been identified as *Paracalais gibboni*. The larvae are reported to be predatory upon the larvae of a large longicorn (*Diotimana undulata* Pascoe) in felled or fallen Hoop pine (*Araucaria cunninghami*) logs. The very active larvae stop feeding between October and December, when they undertake construction of an oval pupal chamber. The pupation takes place during summer months and after a short period of 15-20 days the adult emerges. According to observations by Froggatt the adults emerge between January

and Mareh, although a few earlier records are available. Unfortunately most of the adult specimens do not have data of their capture on the labels so that knowledge of their occurrence is still very slight.

Queensland entomologist Illidge had also informed Froggatt about '*Alaus gigas*' larvae attacking the larvae of longicorn (*Batocera boisduvali*) in native fig trees, '*Alaus sericeus*' attacking *Monohammus* sp. (Cerambycidae) in poison mangrove stems and '*Alaus macleayi*' attacking *Prioninae* sp. in the decaying stems of *Tristania* and *Eugenia* (Myrtle and Lilly-pilly respectively).

As indicated earlier, determination of the '*Alaus*' species by Froggatt is sometimes erroneous and it has not been possible to check the correctness of *gigas* and *sericeus*, but judging from Fig. 8 (Froggatt 1927) the identity of *macleayi* may be accepted as correct.

#### KEY TO THE KNOWN SPECIES OF *Paracalais*

1. Lateral margins of mesosternal cavity distinctly swollen at posterior half, more or less abruptly depressed at the anterior half ..... 2
- Lateral margins of mesosternal cavity of similar thickness on the entire length, not abruptly depressed at the anterior half ..... 4
- 2 (1). Apex of elytra emarginate ..... *gibboni* (Newm.)
- Apex of elytra conjointly rounded, sutural carina extended to form a short spine ..... 3
- 3 (2). Elytra with mottled colour pattern ..... *macleayi* (Cand.)
- Elytra with longitudinal dark lines ..... *gigas* (Cand.)
- 4 (1). Apex of elytra conjointly or individually rounded ..... 5
- Apex of elytra truncate, emarginate or mucronate ..... 12
- 5 (4). Elytra with third interval raised to an elevated ridge or tubercle at the base ..... 6
- Elytra with third interval flat or slightly convex at the base (Norfolk Is.) ..... *nesiotes* sp. n.
- 6 (5). Midlateral mark on elytra distinctly separated from background colour and surrounded by much paler greyish or brownish scales ..... 7
- Midlateral mark on elytra indistinctly separated from background or at most bordered by pale scales only along posterior margin ..... 9
- 7 (6). Midlateral mark elongate, about half the length of elytra ..... *lectilis* (Cand.)
- Midlateral mark small rounded, or irregular ..... 8
- 8 (7). Midlateral mark only one or two intervals wide, widest at the margin of elytra ..... *albatus* (Cand.)
- Midlateral mark extends to fifth interval, widest at the third or fourth interval ..... *pumilus* (Cand.)
- 9 (6). Antennae with segments 4-10 somewhat pentagonal, serrations large ..... *melancholicus* (Cand.)
- Antennae with segments 4-10 rounded or more or less triangular (serrations small) ..... 10
- 10 (9). Elytra conjointly rounded ..... *funebri* (Cand.)
- Elytra individually rounded ..... 11
- 11 (10). Pronotum very convex; midlateral markings on elytra small about 3 intervals wide ..... *fornicatus* sp. n.
- Pronotum somewhat flattened posteriorly and along lateral margins; midlateral markings on elytra up to 7 intervals wide ..... *fumereus* (Cand.)
- 12 (4). Pronotum longer than wide, very convex, not flattened along the lateral margins ..... 13
- Pronotum about as long as wide, flattened along the lateral margins ..... 15
- 13 (12). Elytra with apices emarginate, mucronate on both angles ..... *prosapius* sp. n.
- Elytra with apices truncate, or only slightly emarginate, never mucronate ..... 14
- 14 (13). Pronotum with a pair of large dark spots, midlateral markings on elytra not joined at the suture ..... *darwini* (Btkb.)
- Pronotum with the dark spots small, elongate or almost absent; oblique midlateral markings on elytra joined at the suture forming inverted 'v' pattern ..... *nurinus* sp. n.
- 15 (12). Pronotum with pair of elongate or triangular, more or less distinct dark spots ..... 16



- Dark spots on pronotum entirely absent or inconspicuous if present ..... 17
- 16 (15). Midlateral markings on elytra large, semicircular; entire basal half of elytra dark; dark spots on prothorax triangular ..... *suboculatus* (Cand.)
- Midlateral markings on elytra consisting of longitudinal lines in oblique arrangement; base of elytra with a dark line on either side of scutellum; dark spots on prothorax elongate ..... *hayekae* sp. n.
- 17 (15). Elytra with apices mucronate ..... 18
- Elytra with apices truncate or emarginate ..... 20
- 18 (17). Basal slope of elytra covered with distinctly darker scales than the remaining surface of elytra ..... 19
- Basal slope of elytra covered with the same colour scales ..... *spiciformis* sp. n.
- 19 (18). Anterior margin of pronotum with pair of acute well developed spines ..... *spinicollis* (Zwal.)
- Anterior margin of pronotum with pair of short tubercles only .... *sericeus* (Cand.)
- 20 (17). Apex of elytra truncate with outer angle rounded, sutural carina extended to short spine ..... *victoriae* (Schw.)
- Apex of elytra obliquely truncate or slightly emarginate, both angles similar ..... *prosectus* (Cand.)

### *Paracalais gibboni* (Newman)

(Fig. 6-8; Pl. 43, fig. 1)

*Alaus gibboui* Newman 1857, Trans. ent. Soc. Lond. (N.S.) 4: 51.

*Alaus gibboni* Candèze 1874, Mem. Soc. Sci. Liège (2) 4: 146.

*Alaus prosectus* Froggatt 1925, Austr. For. J. 8 (12): 327, Fig. 1-7.

*Alaus prosectus* Froggatt 1926, Austr. Nat. Sydney 4: 48.

*Alaus prosectus* Froggatt 1927, Forest Insects and Timber Borers, p. 46, Pl. 14, fig. 1-7.

*Alaus gibboni* Nsboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 16.

*Alaus gibboni* Zwaluwerburg 1959, Pacif. Insects 1 (4): 359.

REMARKS: As indicated in the original description 'Mr Gibbon found a single specimen in a sawpit'. Its size was given as 1.5 unc. (=  $1\frac{5}{12}$  in. or 35 mm). Further Newman says that Gibbon 'has with such liberality presented the rarities of his collection to our National Museum' which suggests that the type specimen of *gibboni* should be in the British Museum collection. Miss Hayek informed (in litt.) that the British Museum records show that Gibbon presented 123 specimens of Coleoptera from Moreton Bay to the Museum in 1856, and these specimens should bear the number 1856.1 or 56.1.

There is one example of this species in the British Museum Collection which Zwaluwerburg (1959: 359) has already referred to as possible holotype, and given the measurement of 33 mm. This specimen is undoubtedly that to which Candèze referred (1874: 143) giving the measurement as 35 mm. The discrepancy is probably due to the fact that the prothorax is bent downward in an angle to the abdomen. We can assume that Candèze was looking at the same specimen as Newman. It bears three labels: 1. 'Moreton Bay' (round label). 2. 'Janson Coll. 1903-130'. 3. '*Alaus gibboni* Newm. Cand. Type'—the latter in Janson's handwriting. The size of the specimen agrees. There was apparently only one other specimen of this species labelled 'Browning 63-47' in the British Museum collection at the time that Candèze published his note.

There are two further specimens, both females, from the Janson collection, but from different localities and of different size.

As the search for the possible type specimen in the Hope Museum, Oxford, where part of Newman's collection has been deposited, was unsuccessful, the specimen discussed above has been accepted as being the type of *Alaus gibboni* Newman, and therefore a red type label has been attached to it. This species belongs to one of the largest and most colourful of Australian *Paracalais* and is therefore quite easily distinguished from other species.

DESCRIPTION: Head densely covered with greyish white scales, intermingled with occasional dark ones. Antennae serrate; 2nd segment short, glabrous; 3rd slightly flattened, triangular; segments 4-10 triangular, flattened; 11th elongate recessed near apex.

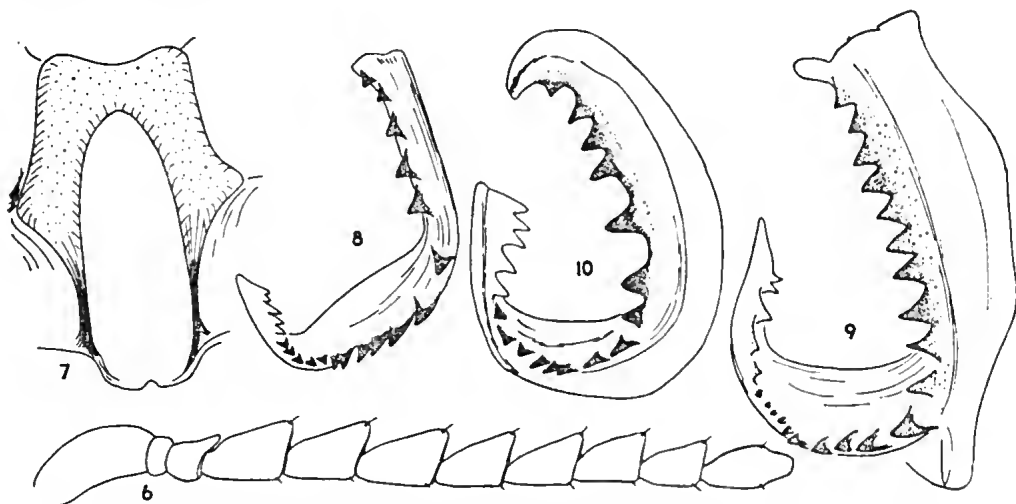


FIG. 6-10—6-8—*Paracalais gibboni* (Newm.); 6—♀ antenna; 7—mesosternal cavity; 8—chitinous collar of bursa copulatrix; 9—*Paracalais macleayi* (Cand.)—chitinous collar of bursa copulatrix; 10—*Paracalais gigas* (Cand.)—chitinous collar of bursa copulatrix.

Pronotum slightly shorter than wide, rounded, widest at the anterior third; anterior margin with a pair of small protuberances; posterior angles acute, diverging and carinate. Scales narrow, elongate, greyish-white, grey or black; the latter forming a pair of elongate spots near the median line; full pattern is shown in Pl. 43, fig. 1.

Scutellum elongate, sides parallel. Elytra gradually and slightly widened to the middle, apex emarginate; third interval elevated near base for short distance only, forming a somewhat elongate tubercule; colour pattern formed by white greyish and black elongate scales, with comparatively very little variation between the examined specimens.

Ventral side densely covered with uniformly buff-coloured scales. Prosternum curved dorsoventrally; anterior margins of prosternal lobe rounded, depressed in the middle; transverse groove if present, incomplete. Mucro distinctly bent near the middle; prosternal grooves short. Lateral margins of mesosternal cavity broad posteriorly, narrow and depressed anteriorly.

DIMENSIONS: Length: ♂ 29-37 mm, ♀ 29-44 mm; width: ♂ 9·2-12 mm, ♀ 10·5-15·5 mm.

SPECIMENS EXAMINED: 19 ♂, 78 ♀. AM, BM, CSIRO, DEI, FTF, JA, MACL, NM, NSWDA, QDPI, QM, QU.

TYPE DATA: Location: BM. Locality: Moreton Bay, Q'land.

DISTRIBUTION: Queensland: Kuranda, Brisbane, Bunya Mts. (Nov., Dec. Jan.), Pine Mountains, Rockhampton; Rivertree; Stanthorpe, Moreton Bay; Blackbutt

(Nov.), Binna Burra (Nov.), Imbil State Forest (May), National Park (Nov.), Corinda, Emu Vale (Feb.). New South Wales: Dorrigo (Nov., Jan.-March Froggatt 1926), Manning R., Illawarra, Brunswick R. The locality of two specimens (females) in DEL is given as 'Melb.' (for Melbourne)—which undoubtedly is erroneous.

Froggatt's description and figures (1925, 1926 and 1927) of *Alaus prosectus* should be referred to this species. Specimens in BM collection labelled 'larvae parasite on longicorn larvae in Hoop pine W. W. Froggatt bred 1926' and also id. '*A. prosectus* Cand. W.W.F.'

### **Paracalais macleayi (Candèze)**

(Fig. 9; Pl. 43, fig. 2)

*Alaus macleayi* Candèze 1857, Mem. Soc. Sci. Liège 12: 235.

*Alaus macleayi* Froggatt 1925, Austr. For. J. 8 (12): 327, Fig. 8.

*Alaus macleayi* Froggatt 1927, Forest Insects and Timber Borers, p. 48, Pl. 14, fig. 8.

*Alaus macleayi* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 16.

This large species appears to be closely related to *Paracalais gigas*, but the absence of dark longitudinal line pattern on elytra makes it easily distinguishable.

**DESCRIPTION:** Head flat, only slightly depressed anteriorly. Antennae short, length about half that of pronotum; second segment very short, round; third slightly longer produced downward to a point, almost triangular; following segments flattened laterally somewhat similar to those in *P. gibboni*.

Pronotum as wide as long, convex transversely; anterior margin with only slight protuberances; posterior angles short, stout, divergent; carina short and close to lateral margin.

Scutellum elongate, centrally and posteriorly depressed, lateral margins parallel. Elytra subparallel, conjointly rounded at the apex; sutural carina extended to a sharp point. Third interval raised to an indistinct low elongate ridge on either side of scutellum. The entire dorsal surface densely covered with pale brownish-white scales, which on pronotum are intermingled with occasional dark ones, thus producing a mottled appearance; the dark scales on the elytra form a well-defined mid-lateral spot on each side and usually about four intervals wide; additional colour markings shown in Pl. 43, fig. 2.

Ventral surface covered with similar scales, also retaining spotted appearance of prosternum. Prosternal lobe separated by more or less indistinct transverse line. Prosternal groove very short. Sides of mesosternal cavity broad and elevated posteriorly; narrowed and lowered anteriorly.

**DIMENSIONS:** Length: ♂ 34-42 mm, ♀ 39-50 mm; width: ♂ 12-14 mm, ♀ 14-15.5 mm.

**SPECIMENS EXAMINED:** 9 ♂, 59 ♀. AM, BM, CALIF, CSIRO, ETS, JA, JS, LG, MACL, NM, NSWDA, QDPI, QM, QU, SAM.

**TYPE DATA:** Location: BM. Locality: New Holland.

**DISTRIBUTION:** Queensland: Gap Creek (Nov.), Cairns, Endeavour R., Finch Hatton (Jan.), Mackay (Jan., Feb.), Stanthorpe (Jan.), Heifer Ck nr. Toowoomba (Jan.), Lamington National Park (Feb.), Moreton Bay (Feb.), Mt. Glorious (Feb.), Southport, Rivertree, Taringa (Feb.), Mt. Gravatt (Apr.), Barden (Nov.), Brisbane, Bowen, Eidswold, Gladstone. New South Wales: Ingleburn (Apr.), Narrabri (Nov. Dec.), Woy Woy (Jan.), Tweed R., Sydney, Manning R., Ropes Ck, Ash Island, Kurrajong, Grafton (Dec.), Bogan R., Inverell, Gunnedah

(Jan.), Port Macquarie (Jan., Mar.), Richmond, Narrabreen, Wingham, Clarence R. (Dec.), Campden Haven (Jan.).

***Paracalais gigas* (Candèze)**

(Fig. 10; Pl. 43, fig. 3)

*Alaus gigas* Candèze 1857, Mem. Soc. Sci. Liège 12: 234.

*Alaus gigas* Gestro 1875, Ann. Mus. Stor. Nat. Genova 7: 10.

*Alaus gigas* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 16.

This large Australian species with longitudinally striate elytra is easily distinguished from all other species and should produce no difficulties in identification.

**DESCRIPTION:** Head flat, only slightly inclined along anterior margin. Antennae short, segments of similar proportions to those of *Paracalais gibboni*.

Pronotum approximately as wide as long, or slightly wider than long; very convex transversely with weak longitudinal median furrow; anterior margin with two small tubercles on either side of midline; posterior angles short, rather blunt, divergent, but extreme tips bent down and backwards; carina short and close to lateral margin.

Scutellum flat, depressed medially, sides somewhat parallel. Elytra evenly narrowed at posterior third, rounded at apex, sutural carina produced to a sharp spine. Third interval raised to a low tubercle on either side of scutellum. Entire dorsal side densely covered with greyish white scales, the line pattern formed by very dark almost black scales, with, in places, lightly coloured tips. Colour pattern as shown in Pl. 43, fig. 3.

Entire ventral surface densely covered with greyish white scales similar to those on dorsal surface. Prosternal groove very short, opening up to a flat suture. Prosternal usually separated by transverse groove which may be incomplete medially; anterior margin with slight depression medially. Mesosternal cavity with the margins widened and elevated posteriorly, depressed and narrowed anteriorly.

**DIMENSIONS:** Length: ♂ 32-38 mm; ♀ 36-51 mm; width: ♂ 10.5-11 mm; ♀ 11-15 mm. (Miss Hayek informed (in litt.) that the type specimen is only 45 mm long, although the original description gives the size as 50 mm.)

**SPECIMENS EXAMINED:** 12 ♂, 31 ♀. AM, BM, CALIF, DEI, MACL, NM, QDPI, QM, QU, SAM.

**DISTRIBUTION:** Queensland: Bunya Mts. (Feb.); Brisbane: St. Lucia (Feb.); National Park, Q'ld. (Nov.); Mt. Tambourine (Nov.), Rivertree. New South Wales: Lismore (Aug.); Richmond R.; Broken Hill. The locality 'Melb.' (for Melbourne) on both specimens from DEI is undoubtedly erroneous.

**TYPE DATA:** Location: BM. Locality: New Holland.

***Paracalais nesiotēs* sp. n.**

(Pl. 43, fig. 4)

This medium-sized species, known only from Norfolk Island, resembles in general colouring the much larger Australian *Paracalais macleayi*, from which it could be separated by the narrow and gradually anteriorly sloping lateral margins of the mesosternal groove.

**DESCRIPTION:** Head slightly depressed anteriorly. Antennae short, second and third segments almost equal in length and globular, third with short pointed projection on distal margin; fourth segment longer than second and third together; last segment recessed near apex.

Pronotum about as wide as long, widest at middle; in females almost circular, in males slightly elongate; a weak elevated median line visible, posterior angles short divergent, carinate; carina closer, almost parallel to lateral margin.

Scutellum indistinctly pentagonal or almost elongate oval; only slightly depressed in middle.

Elytra gradually widening towards the middle then narrowed to conjointly rounded apices; sutural carina terminates into a minute point; third interval at base, although slightly higher than second and fourth, does not form ridge or tubercle.

Entire underside and legs covered with greyish to yellowish white pubescence. Lateral margins of mesosternal cavity not widened, gradually sloping anteriorly.

DIMENSIONS: Length: ♂ 24·5; ♀ 24-27·5 mm; width: ♂ 8 mm; ♀ 7·5-9 mm.

TYPE MATERIAL: Holotype ♀ Norfolk Island (NM); Allotype ♂; Paratype ♀ Norfolk Island (SAM); 2 paratype ♀♀ Norfolk Island (AM).

DISTRIBUTION: Known only from Norfolk Island, Pacific Ocean (29° 02'S; 167° 57'E).

### **Paracalais lectilis (Candèze)**

(Pl. 43, fig. 5)

*Alaus lectilis* Candèze 1897, Mem. Soc. Sci. Liège (2) 19: 15.

*Alaus lectilis* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 16.

This species has not been recognized since it was first described in 1897 and so far there are only three specimens known to exist in the various collections. It could be easily recognized by the distinct lateral markings and the conjointly rounded tips of the elytra.

DESCRIPTION: Head with median depression, deepest anteriorly. Antennae short, not reaching front coxal cavities, arrangement of segments similar to that of *P. gibboni*.

Pronotum about as wide as long, anterior margin without protuberances; posterior angles rather short, divergent; carina short, closer to the lateral margin. Scutellum with sides parallel, median posterior section depressed. Elytra with parallel sides, narrowing at posterior third, apex conjointly rounded. Third interval raised to a short elevated ridge. The colour pattern as shown in Pl. 43, fig. 5. Prosternal lobe separated by transverse groove which may be incomplete medially; sides of mesosternal cavity parallel neither widened nor depressed.

DIMENSIONS: Length: ♂ ♀ 22-26·5 mm; width: ♂ ♀ 7-8 mm.

SPECIMENS EXAMINED: 1 ♂; 2 ♀.

DISTRIBUTION: Queensland: ex Kershaw coll., no further data (NM). New South Wales: Mullaley, Dec. 1956, F. E. Wilson (NM).

TYPE DATA: Location: IRSNB, ♀ 'New South Wales/*Alaus lectilis* det. E. Candèze/n. sp. 1895 *Lectilis* N.S.W. Cand. St./Collection Candèze/cf. Mem. Soc. Roy. Sc. Liège 2<sup>e</sup> sér. 1897; XIX, p. 15'.

### **Paracalais albatus (Candèze)**

(Fig. 11-13; Pl. 43, fig. 6)

*Alaus albatus* Candèze 1897, Mem. Soc. Sci. Liège (2) 19: 15.

*Alaus albatus* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 15.

*Alaus albatus* Zwaluwenburg 1959, Pacif. Insects 1 (4): 355.

DESCRIPTION: This is a medium size whitish grey species with short broad and moderately convex pronotum. Entire ventral side and legs of similar colour. Scales

covering pronotum and elytra narrow and pointed. Colour pattern somewhat indistinct, mottled. Pronotum with a distinct narrow white median line and on either side of it a broader, darker but less distinct line. Small dark spot located on either side of the median line about a third way from the anterior margin; another short dark oblique spot located just posteriorly off the eyes. Blackish lateral spot on elytra small, extending the width of only two intervals. Small dark spots scattered irregularly on pronotum and elytra.

Head moderately depressed mid-dorsally. Antennae short, about two-thirds length of pronotum in female, but equal to length of pronotum in male; 2nd segment very short, rounded; 3rd segment slightly longer with apical margin produced laterally to a pointed projection.

Pronotum as wide or slightly wider than long, widest at the anterior third; anterior margin without projections; posterior angles, short, carinate divergent.

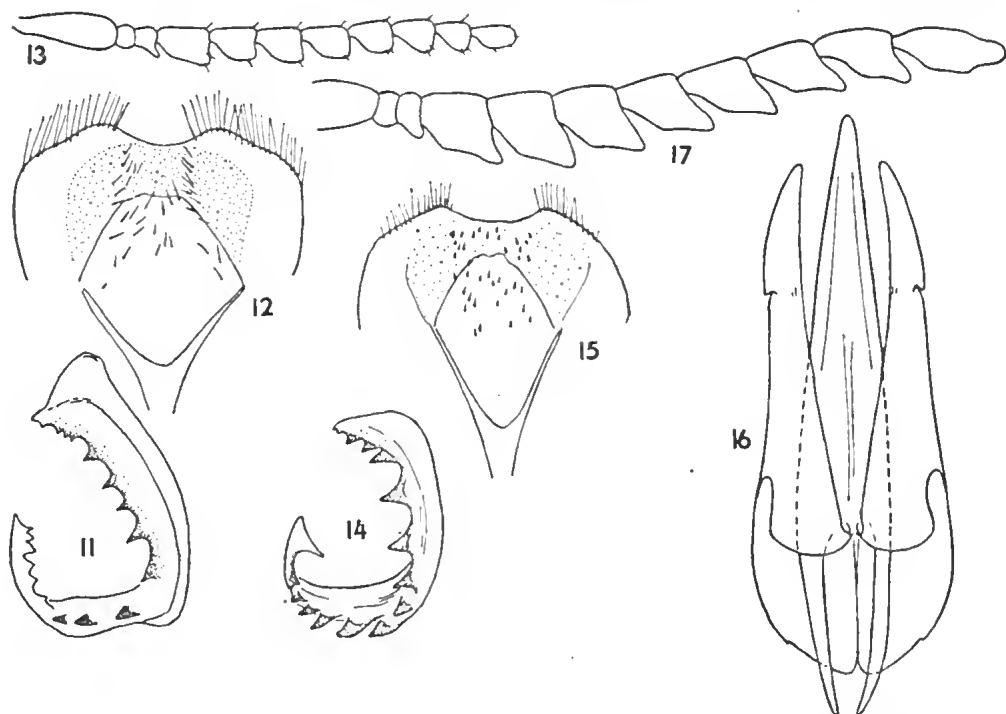


FIG. 11-17—11-13—*Paracalais albatus* (Cand.); 11—chitinous collar of bursa copulatrix; 12—♀ 8th sternite; 13—♀ antenna; 14-15—*Paracalais pumilus* (Cand.); 14—chitinous collar of bursa copulatrix; 15—♀ 8th sternite; 16-17—*Paracalais melancholicus* (Cand.); 16—Type ♂, aedeagus; 17—♂ antenna.

Antennal groove very short. Scutellum elongate, sides parallel, posterior end rounded and slightly depressed. Elytra slightly increase in width to the middle, then curve posteriorly to rounded apices which occasionally tend to be indistinctly truncate. Third interval raised at the anterior end forming a low ridge which, together with the area between, and for a short distance posteriorly, is uneven—vermiculate. Sides of the mesosternal cavity not elevated or otherwise enlarged, sloping anteriorly.

The photograph reproduced is that of the type ♂ kindly provided by Dr A. Villiers of Museum National d'Histoire Naturelle, Paris.

DIMENSIONS: Length: ♂ 18 mm; ♀ 20 mm; width: ♂ 5 mm; ♀ 6.2 mm.

SPECIMENS EXAMINED: 1 ♀ Mutchilba, N. Qld. Dec. 1933. A. D. Selby (NM); 1 ♂ 'Queensland/Coll. Franklin Müller/*Alaus albus* Cand. Compari au type Fautiaux det' (DEI).

DISTRIBUTION: North Queensland.

TYPE DATA: Location: MHN, Paris. ♂; Northern Australia (without further data).

It was stated in the original description that the type is from Fleutiaux collection; the locality was given as Northern Australia and the size as 20 mm × 6 mm. Van Zwaluwenburg examined the specimen and in 1959 published the following note (p. 355). 'Type: PARIS ? (box 52), probably male; 18 mm; Tasmania: identified by Candèze: "Type"' (Fleutiaux's label). The type locality is northern Australia. Generally whitish with pair of small blackish markings (anteriorly divergent) on pronotum, and a short, blackish spot (2 intervals wide) on side of each elytron at about the middle. No specimen of *albus* was found in the IRSNB. The label 'Tasmania' is definitely misplaced because there is no record of this genus being found in Tasmania.

### *Paracalais pumilus* (Candèze)

(Fig. 14-15; Pl. 44, fig. 7)

*Alaus pumilus* Candèze 1874, Mem. Soc. Sci. Liège (2) 4: 149.

*Alaus pumilus* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 16.

DESCRIPTION: Small, rather distinctly coloured species, covered with greyish white scales, pattern of brownish-black.

Head slightly depressed anteriorly. Antennae short, reaching back as far as front coxal cavities; 3rd segment only slightly longer than 2nd, following segments subtriangular, last elongate, recessed at apex.

Pronotum slightly longer than wide, strongly convex, lateral margins curved, anterior margin with a pair of small tubercles; posterior angles divergent, carina present, short, running close to lateral margin.

Scutellum pentagonal with posterior fifth the widest, middle slightly depressed. Elytra widest at posterior third, apex rounded; third interval elevated to short ridge near the base.

Scales on the ventral surface pale buff. Prosternal lobe separated by more or less distinct transverse groove. Prosternal groove very short; sides of mesosternal cavity parallel, neither widened nor depressed.

DIMENSIONS: Length: ♂ 13-18 mm; ♀ 12.5-20 mm; width: ♂ 3.5-5.5 mm; ♀ 3.5-6 mm.

SPECIMENS EXAMINED: 7 ♂, 17 ♀. AM, BM, CSIRO, QDPI, MACL, NM, QU, SAM.

DISTRIBUTION: Queensland: Rockhampton, Pt. Dennison, Brisbane, Bowen, Eukey (Jan.). New South Wales: Uralla, Tweed River, Illawarra.

TYPE DATA: Location: BM; Type ♀ (15 mm) labelled 'N. Holl. Q'land. Rockhampton/Janson Coll. 1903—130/*Alaus pumilus* Cdz. N. Austr. Tp./*Alaus pumilus* Cdz. Type'. Locality: Rockhampton, Q'ld.

**Paracalais melancholicus** (Candèze)

(Fig. 16-17; Pl. 44, fig. 8)

*Alaus melancholicus* Candèze 1874, Mem. Soc. Sci. Liège (2) 4: 147.*Alaus melancholicus* Elston 1930, Ark. Zool. 22: 7.*Alaus melancholicus* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 16.

The very dark overall appearance, oblique black band and more deeply serrate antennae are the main distinguishing features of this species.

DESCRIPTION: Head slightly concave anteriorly. Antennae deeply serrate; 2nd and 3rd segment approximately equal in length; the third produced downward to a sharp point; segments 4 to 10 as shown in Fig. 17, terminal segment deeply recessed near the apex. Antennae extending back as far as, or further than, front coxal cavities.

Pronotum elongate almost cylindrical; posterior angles short, divergent, carinate.

Scutellum usually inclined to parallel or widest near posterior third, more or less depressed in the middle. Elytra gradually narrowed toward rounded apex. Third interval only slightly elevated to a short ridge near the base.

DIMENSIONS: Length: ♂ ♀ 18-25 mm; width: ♂ ♀ 6-7.5 mm.

SPECIMENS EXAMINED: 10 ♂, 1 ♀. BM, NM, SAM, MACL.

DISTRIBUTION: Queensland (no further details) Type; A. C. T. Canberra (Jan.); Victoria—Melbourne (?); Dolly's Dell, Grampians (Feb.).

TYPE DATA: Location: BM labelled: 'N. Holl. Q'ld./Janson Coll. 1903 130/*Alaus melancholicus* Cdz. Type'. The latter label in Janson's handwriting.

**Paracalais funebris** (Candèze)

(Fig. 18-20; Pl. 44, fig. 9)

*Alaus funebris* Candèze 1857, Mem. Soc. Sci. Liège 12: 233-234.*Alaus funebris* Heller 1900, Denkschr. med.-nat. Ges. Jena 8 (17): 620.*Alaus funebris* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 16.

The name *funebris* has been widely used for a great number of specimens belonging to six or seven species. Following the examination of a large number of specimens from various collections it was found that the true *funebris* is apparently quite a rare species, and only two other specimens beside the type, have been ascribed to it.

DESCRIPTION: General colour rather dark greyish brown, pronotum with darker median line, dark lateral spots on elytra indistinct. Ventral surface of similar general colour to that of dorsal side.

Head slightly concave anteriorly. Antennae serrate, reaching just beyond the middle of prothorax; 2nd segment small, globular; 3rd segment small, triangular; segments 4-10 diminishing in length, somewhat pentagonal, flattened laterally; terminal segment distinctly recessed on one side near apex.

Pronotum widest at anterior third, longer than wide, central section of the anterior margin straight, produced forward with slight protuberance on either side.

Elytra parallel for half the length then narrowing to the evenly rounded apex. Third interval raised to a distinct tubercle near the base.

Prosternal lobe separated by indistinct transverse groove, prosternal groove short; sides of mesosternal cavity parallel, narrow and not depressed.

DIMENSIONS: Length: ♀ 23-29 mm; width: ♀ 7-9 mm.

SPECIMENS EXAMINED: 3 ♀. 1 ♀ type (data below), 1 ♀ Yaamba, Q. 5 Jan. 1962 L. A. Powell (QM), 1 ♀ New Holland (BM).



DISTRIBUTION: Queensland: Moreton Bay, Yaamba (Jan.).

TYPE DATA: Location: BM-labelled: 'N. Holl. Moreton Bay/*Alaus funebris* Cdze, Type ex Coll. Deyrolle/Janson Coll. 1903—130/'. On the other side glued on '*funebris* Cdze' (Candèze handwriting).

***Paracalais fornicatus* sp. n.**

(Fig. 21-23; Pl. 44, fig. 10)

This species is distinguished from *P. funereus* and other related species in Australia by its very convex pronotum. The usual colour pattern as shown on Pl. 44, fig. 10, indicates pale brownish-white scales on the sides of the pronotum and an oblique area of the same colour on the posterior half of the elytra. The lateral marking, blackish brown, extends only the width of three intervals; the entire basal section of elytra is dark brown.

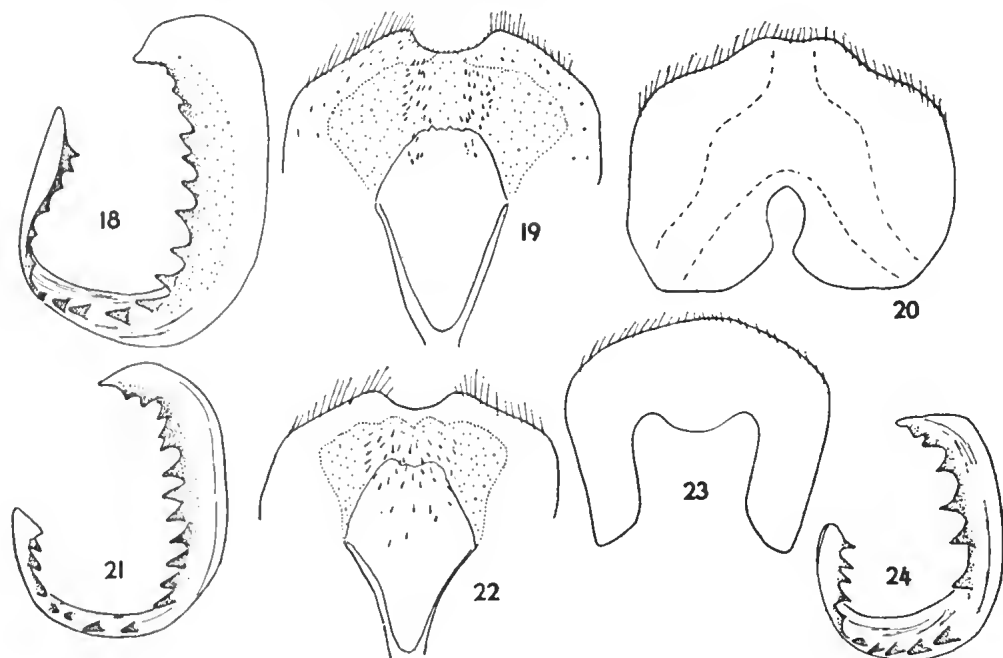


FIG. 18-24—18-20—*Paracalais funebris* (Cand.) Type ♀; 18—chitinous collar of bursa copulatrix; 19—♀ 8th sternite; 20—♀ 8th tergite; 21-23—*Paracalais fornicatus* sp. n., Holotype ♀; 21—chitinous collar of bursa copulatrix; 22—♀ 8th sternite; 23—♀ 8th tergite; 24—*Paracalais funereus* (Cand.) Neotype ♀—chitinous collar of bursa copulatrix.

DESCRIPTION: Head with slight median depression. Antennae short, barely reaching the front coxal cavities; 2nd and 3rd segments very short, globular and approximately of equal length; segments 4-10 subtriangular, diminishing in length; 11th elongate, recessed near the apex.

Scutellum elongate pentagonal, widest at the posterior third where the lateral margins are more or less elevated. Elytra gradually and slightly widened to the middle then curved posteriorly to rounded apices, which occasionally are indistinctly truncate. Third interval at the base raised to an elongate tubercle.

The entire ventral side more or less uniformly brownish.

**DIMENSIONS:** Length: ♂ 19-21 mm, ♀ 21-26 mm; width: ♂ 6-6.5 mm, ♀ 6.5-8 mm.

**TYPE MATERIAL:** Holotype ♀ Endeavour R., Queensland (NM); Allotype ♂ Northern Queensland (NM); Paratypes: 1 ♂ Crystal Cascades, via Cairns, N.Q. 22.XII.1964. G. Monteith (QU: C-155), 4 ♀ Endeavor R., N. Q'ld. (1 ♀ DEI, 2 ♀ MACL, 1 ♀ NM), 1 ♀ Churchill Ck Mt. Lewis Road via Julaten 27.XI.1965, N. Q'ld. G. Monteith (NM) (Pl. 44, fig. 10), 2 ♀ Gap Ck, 6 miles N. of Bloomfield R., N. Q'ld. 13-14.XI.1965. G. Monteith (QM: T-6533, QU: C-154), 1 ♀ Coen Distr. Cape York, Q'ld. H. Hacker (DEI) 'id. Fleutiaux *Alaus melancholicus* Cand.' Other specimens examined: 1 ♀ Johnstone R., 1897 (QDPI 10964).

**DISTRIBUTION:** North Queensland.

### ***Paracalais funereus* (Candèze)**

(Fig. 24; Pl. 44, fig. 11)

*Alaus funereus* Candèze 1865, Mem. Cour. Acad. R. Belg. 17: 17.

*Alaus funereus* Candèze 1874, Mem. Soc. Sci. Liège (2): 4: 146.

*Alaus funereus* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 16.

It is rather unfortunate that the type of *funereus* has been lost (Hayek in litt.), but among other British Museum material there is another specimen bearing Janson's label '*Alaus funereus* Cdze. ex Coll. Candèze'. The same name on another label and written by Candèze is glued on the other side of Janson's label. This information provides sufficient evidence that Candèze had identified the specimen as *funereus*, therefore it has been selected as neotype ♀ and labelled as such.

*P. funereus* closely resembles *P. melancholicus* (Cand.), but differs in the shape of antennae (particularly in the males) and in the form of the lateral marking on elytra.

**DESCRIPTION:** Head with slight median depression anteriorly. Antennae brownish, short, extending back as far as the front coxal cavities in the male, shorter in the female. Pronotum widest at the anterior third; anterior margin with a pair of distinct protuberances; posterior angles short, divergent, carinate.

Scutellum somewhat pentagonal or mitre-shaped with lateral margins elevated, particularly at the posterior third, apex and centre depressed. Elytra terminates into individually rounded apices. Third interval raised to a distinct tubercle at the base.

The sternum covered with yellowish brown scales in contrast with the ashy grey dorsal scales. Prosternal lobe separated by indistinct transverse groove. Lateral margins of mesosternal cavity parallel, narrow, not depressed.

**DIMENSIONS:** Length: ♂ ♀ 20-24 mm; width: ♂ ♀ 6.5-7.5 mm.

**SPECIMENS EXAMINED:** 9 ♂, 22 ♀. BM, CSIRO, MGF, NM, QU.

**DISTRIBUTION:** Queensland: Moreton Bay, Brisbane, Bowen, Southport, Gatton. New South Wales: Tweed R., Sydney, Maitland, Hunter R. A.C.T.: Canberra. Victoria: Gippsland?

**TYPE DATA:** BM Neotype ♀ North N. Holl./Janson Coll. 1903-130/'*Alaus funereus* Cdze. ex Coll. Candèze (Janson handwriting) *A. funereus* Elat. n. Cdze. Nord. Austr./Genitalia prep. E-533 Neboiss 1966 Neotype ♀ *Paracalais funereus* (Cand.) det. Neboiss 1966'.

**Paracalais prosapius** sp. n.

(Pl. 44, fig. 12)

DESCRIPTION: Moderately small species, rather cylindrical in appearance; covered with greyish-white and black scales; prothorax proportionally long as compared with elytra in other species. Superficially resembles *Paracalais darwini* (Blkb.), but differs by having slightly smaller patches of dark scales on pronotum and mucronate apices of the elytra.

Head with somewhat triangular depression in front. Antennae short; 2nd segment rounded, 3rd slightly longer than 2nd, subtriangular; 4th segment the longest, the following ones shorter and subequal; 11th segment slightly longer than preceding ones, somewhat oval, recessed near apex.

Pronotum longer than wide, anterior margin with a pair of very small tubercles, which are more pronounced in the female; strongly convex, fine elevated median line visible on the posterior half of the pronotum.

Scutellum pentagonal, widest at the posterior third, slightly depressed. Elytra subparallel for two-thirds of the length, then gradually curved towards mucronate apices; third interval elevated on basal slope.

Entire underside and legs covered with greyish white scales. Lateral margins of the mesosternal cavity narrow, horizontal.

DIMENSIONS: Length: ♂ 11.5-15.5 mm, ♀ 18 mm; width: ♂ 3-4 mm, ♀ 5 mm.

TYPE MATERIAL: Holotype ♀ Moa, Banks Island, Torres St. 20 Jan. 1920, W. McLennan; caught on cut trees of Moreton Bay Ash and *Alpinia* at night; Allotype ♂ Moa, Banks Island, Torres St., 18 Dec. 1919, W. McLennan; Paratype ♂ loc. as Holotype, 18 Jan. 1920, caught at light K47753/; all in AM.

DISTRIBUTION: Known only from Banks Island, Torres Strait (10° 12'S, 142° 16'E).

**Paracalais darwini** (Blackburn)

(Fig. 25-28; Pl. 45, fig. 13)

*Alaus darwini* Blackburn 1890, Proc. Linn. Soc. N.S.W. (2) 4: 1259-1261.

*Alaus darwini* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 16.

This species is known from a single specimen—the type male. It is characterized by the pronotum being distinctly long and convex.

DESCRIPTION: Head centrally depressed, antennae very short, only about two-fifths length of pronotum; 2nd segment short and rounded; segments 3-10 somewhat triangular; last segment oval, slightly longer than preceding one.

Pronotum densely covered with scales, but in denuded areas exposed integument densely punctate with fine punctures; the median line shows as an elevated ridge; the dark scales of the pronotum form a large patch on either side of the median line on the anterior half; anterior margin slightly produced forward just above the sides of the head; posterior angles abruptly flattened, short, pointed and carinate. Elytra somewhat parallel, evenly rounded toward the apices which are lightly emarginate-truncate; colour and pattern have been extensively described by Blackburn (1890). Third interval raised to a short elevated ridge.

Prosternal grooves distinct, almost to the full length of the antennae; a depression accommodates the anterior pair of legs. In cross section prothorax differs considerably from most other species by having lateral margins indicated by rather indistinct ridge and not flattened.

DIMENSIONS: Length: ♂ 19 mm; width: 5.2 mm.

SPECIMENS EXAMINED: Type ♂.

DISTRIBUTION: Northern Territory.

TYPE DATA: Location: BM. Locality: Northern Territory (without further data).

Following the detailed description Blackburn included a note referring to two *Alaus* specimens from King's Sound, Western Australia which W. Macleay (1888: 1240) regarded as variety of *A. funebris* Cand. Without seeing the specimens Blackburn believed them to be *A. darwini*. These specimens were located in the Macleay Museum and were identified as *Paracalais suboculatus* Cand.

***Paracalais murinus* sp. n.**

(Pl. 45, fig. 14)

This grey and black medium-size species is somewhat close to *Paracalais funereus* but could be separated by having the mid-lateral marking on elytra in a form of distinct oblique bar joined at the suture and forming inverted 'v' pattern. Prosternal grooves longer and more distinct.

DESCRIPTION: Head depressed anteriorly. Antennae short; fourth segment about as long as second and third segment together, the following ones subequal, last segment slightly longer, recessed near the apex.

Pronotum longer than wide, distinctly convex, anterior margin with a pair of small tubercles on either side of median line; posterior angles short, earina distinct; disc elevated at the base.

Scutellum elongate pentagonal, slightly depressed posteriorly. Elytra subparallel, rounded at the posterior third apices, narrowly truncate. Third interval raised to distinct tubercle.

The underside covered with greyish white scales, irregularly intermingled with occasional dark ones. Prosternal groove gradually widens posteriorly and reaches front coxal cavities.

DIMENSIONS: Length: ♂ 28.5-31 mm; ♀ 33 mm; width: ♂ 6-7 mm; ♀ 7 mm.

TYPE MATERIAL: Holotype ♀, allotype ♂ (NSWDA), paratype ♂ (NM). Narrabri. Agr. Res. Station, N.S.W., 21 Nov. 1965. Collected at Mereury Vapour Light; W. E. Wright; paratype ♂ Bogan R., N.S.W. J. Armstrong ex F. E. Wilson collection (NM) (this specimen is discoloured yellowish).

DISTRIBUTION: New South Wales.

***Paracalais suboculatus* Candèze**

(Fig. 29-30; Pl. 45, fig. 15)

*Alaus suboculatus* Candèze 1857, Mem. Soc. Sci. Liège 12: 229.

*Alaus variegatus* Schwarz 1902, Dtsch. ent. Z. 1902: 114.

*Alaus suboculatus* Schwarz 1906, Gen. Ins. 46: 38.

*Alaus variegatus* Schwarz *ibid.* Pl. 2, fig. 4.

*Alaus suboculatus* Fleutiaux 1907, Bull. Soc. ent. Fr. 1907: 162.

*Alaus suboculatus* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 17.

This medium-size species with its distinct colour pattern is readily distinguished from all other Australian species. Particularly noticeable is the pair of dark, somewhat triangular, spots on the pronotum and large rounded mid-lateral marks on the elytra.

DESCRIPTION: Head slightly depressed anteriorly. Antennae reaching back almost as far as the front coxal cavities; second segment very short, rounded; third

almost twice as long, produced downward to a point; fourth to tenth diminishing in length, flattened laterally; the last segment elongated, recessed at the apex.

Pronotum about as long as wide or slightly longer than wide; anterior margin with pair of small protuberances, posterior angles short, divergent; carina distinct,

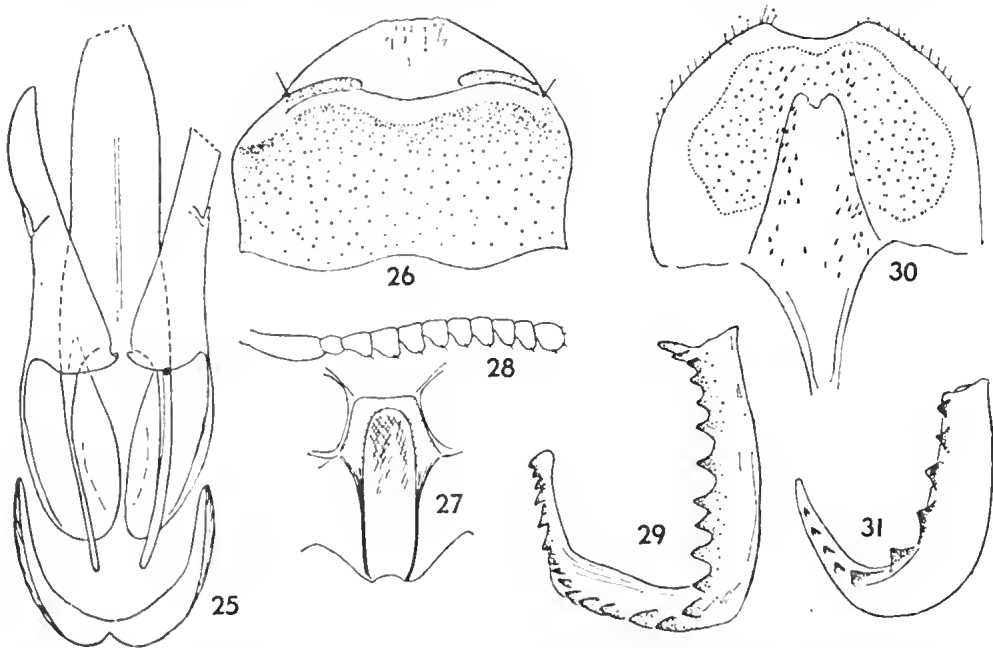


FIG. 25-31—25-28—*Paracalais darwini* (Blkb.) Type ♂; 25—aeagus; 26—♂ 8th tergite; 27—mesosternal cavity; 28—antenna; 29-30—*Paracalais suboculatus* (Cand.); 29—chitinous collar of bursa copulatrix; 30—♀ 8th sternite; 31—*Paracalais hayekae* sp. n., Paratype ♀, chitinous collar of bursa copulatrix.

considerably elevated; coverage of scales very dense, anterior half lightly coloured yellowish or greyish white, posterior half darker, brown or blackish brown; the pair of subtriangular dark spots at the middle usually bordered with pale scales.

Scutellum flat, depressed posteriorly, lateral margins somewhat parallel. Elytra subparallel to the middle then gradually narrowed; apex truncate. Third interval raised to an elevated ridge which sometimes forms an elongated tubercle.

On the ventral surface colour mostly yellowish brown except for section between second and third pair of legs where it is greyish white. Prosternal groove short, suture flat; prosternal lobe separated by transverse depression which is more distinct on either side than in the middle. Mucro with distinct longitudinal groove from base to about half its length. Lateral margins of the mesosternal cavity slightly depressed in the middle, narrow but elevated anteriorly.

DIMENSIONS: Length: ♂ 18-26 mm; ♀ 17.5-31 mm; width: ♂ 6.5-8.5 mm; ♀ 7-10 mm.

SPECIMENS EXAMINED: 5 ♂, 29 ♀. BM, DEI, NM, SAM, QU, MACL, FTF, AM, CSIRO, QM.

DISTRIBUTION: Queensland: Cooktown, Chillagoe, Winton, Somerset, Groote Eylandt, Cunnamulla (Dec.). Western Australia: Nicol Bay, Dedari (Feb.), Kings

Sound, Tambrey, Roebuck Bay, Cue, Lake Austin, Kimberleys Research Stn. Northern Territory: Port Darwin, Hermansburg.

TYPE DATA: Location: BM. Locality: New Holland. Type of *variegatus* Schw. DEI 2 specimens both labelled 'Queensland/Coll. Schwarz/Cotypes/*variegatus* Schw.'

***Paracalais hayekae* sp. n.**

(Fig. 31; Pl. 45, fig. 16)

This large and spectacular species from North Queensland closely resembles *Paracalais gibboni*, but can be easily separated by its general brownish colour, dark elongate mark on either side of scutellum and shape of pronotum.

DESCRIPTION: Head with central depression covered with light buff scales. Antennae short, with similar segmental proportions to those of *P. gibboni*.

Pronotum as long as, or slightly longer than wide and widest at the middle; anterior margin with two distinct protuberances; posterior angles short, stout, divergent; carina indistinct, very close to the lateral margin; median line well defined, spot of dark brownish-black scales on either side near the middle; scales elongate, light to warm buff.

Scutellum with lateral margins somewhat parallel; scales warm buff with paler tips, along posterior margin closer together forming a light buff border. Elytra subparallel, gradually rounded towards truncate apices; scales elongate, of light and warm buff, and brownish black. Colour pattern characterized by an elongated brownish-black patch on either side of the scutellum, same colour arrangement of lines near middle and apex as shown in Pl. 45, fig. 16. Third interval raised to form a tubercle.

Scales on ventral surface less dense, colour more greyish than buff. Prosternal groove very short, opening into gradual depression; prosternum slightly curved dorsoventrally, apex of mucro slightly bent. Sides of mesosternal cavity broad along the posterior half; narrow at the anterior half, not depressed.

DIMENSIONS: Length: ♂ 32 mm, ♀ 30-41 mm; width: ♂ 10 mm, ♀ 9-13 mm.

TYPE MATERIAL: Holotype ♀ Coen Distr. Cape York, Queensland. H. Hacker (NM); allotype ♂ Coen R., Q. W. D. Dodd (SAM); paratypes: 3 ♀ Coen R., Q. W. D. Dodd (NM) 4 ♀ Coen Dist. Cape York, Queensland, H. Hacker (IRSNB, MACL, SAM); 1 ♀ Coen, N.Q. H. Hacker, Dec. 1905 (QM: T-6534); 1 ♀ Coen, N.Q. 5 Dec. 1905 (QU: C-146); 1 ♀ Cooktown, N.Q. H. Hacker (CSIRO); 1 ♀ no loc. (QU: C-147). Other material examined: 2 ♀ no loc. (QM, QU), both damaged specimens.

DISTRIBUTION: North Queensland.

This species has been dedicated to Miss Christine von Hayek of the British Museum (Nat. Hist.), London, in recognition of her assistance and advice.

***Paracalais spiciformis* sp. n.**

(Pl. 46, fig. 19)

Moderately large species with rather distinctly posteriorly tapering appearance, and comparatively large pronotum. It resembles *Alaus constrictus* Schwarz, but is larger and with distinctly mucronate apices of the elytra.

DESCRIPTION: Head rather square, centrally depressed. Antennae short, second and third segments globular, third with pointed projection on distal margin.

Pronotum about as wide as long, mid-section of anterior margin prominent, disc elevated at base; posterior angles short, carinate.

Scutellum elongate pentagonal, slightly depressed posteriorly. Elytra subparallel near base then gradually tapering to emarginate mucronate apices. Third interval elevated to slightly elongate tubercle.

Entire underside covered with greyish to yellowish white scales. Lateral margins of mesosternal cavity subhorizontal, not widened.

DIMENSIONS: Length: ♀ 30-32 mm; width: 9.5-10.5 mm; ♂ unknown.

TYPE MATERIAL: Holotype ♀ (SAM); 2 paratypes ♀ Pt. Darwin, Northern Territory (Feb.) ex Griffith Collection (SAM, NM).

DISTRIBUTION: Northern Territory.

**Paracalais spinicollis (Zwaluwenburg)**

(Fig. 32-33; Pl. 45, fig. 17)

*Alaus spinicollis* Zwaluwenburg 1951, Haw. Ent. Soc. Proc. 14: 323.

*Alaus spinicollis* Zwaluwenburg 1959, Pacif. Insects 1 (4): 362.

Originally this species was described from material collected in New Guinea, but the examination of Australian material showed clearly its existence on this continent.

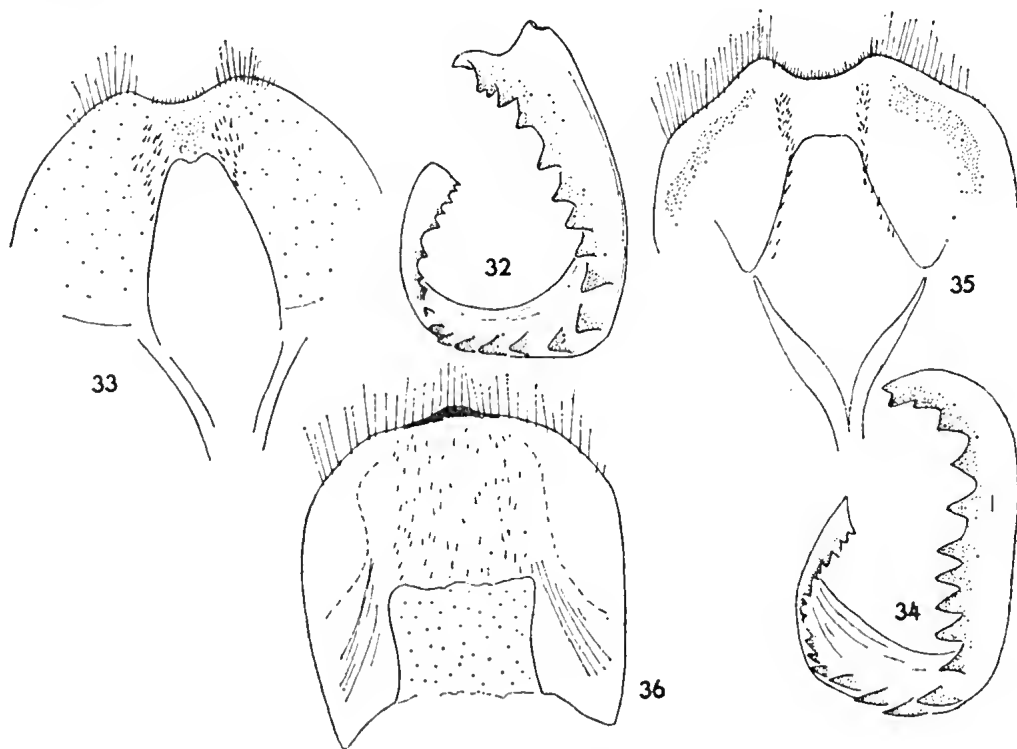


FIG. 32-36—32-33—*Paracalais spinicollis* (Zwal.) Paratype ♀ (New Guinea); 32—chitinous collar of bursa copulatrix; 33—♀ 8th sternite; 34-36—*Paracalais sericeus* (Cand.); 34—chitinous collar of bursa copulatrix; 35—♀ 8th sternite; 36—♀ 8th tergite.

**DESCRIPTION:** Head slightly concave anteriorly, posterior position more or less flattened. Antennae short, extending just beyond middle of prothorax in males and slightly shorter in females; second segment very short; third slightly longer, sub-triangular; segments 4-10 somewhat triangular; last segment elongated, recessed near the apex.

Pronotum widest at anterior third, slightly longer than wide; anterior margin produced into a sharp pointed spine on either side of the midline; posterior angles acute, divergent, carinate.

Scutellum flat, depressed at posterior third, where it is widest. Elytra subparallel to the midlateral marking, which in Australian specimens is four intervals wide (in majority of New Guinea specimens examined, three intervals wide); third interval raised anteriorly to a somewhat rounded tubercle, tips individually emarginate, equally and strongly mucronate on both angles.

**DIMENSIONS:** Length (Australian specimens): ♀ 25-28 mm; width: ♀ 7.5-8 mm.

**SPECIMENS EXAMINED:** 4 ♀. NM, QU, DEI.

**DISTRIBUTION:** North Queensland: Coen, Iron Range (Nov.) and New Guinea.

**TYPE DATA:** Location: BM. Locality: Humboldt Bay Distr., Bewani Mts., N.G. (West Irian).

### ***Paracalais sericeus* (Candèze)**

(Fig. 34-36; Pl. 45, fig. 18)

*Alaus sericeus* Candèze 1874, Mem. Soc. Sci. Liège (2) 4: 148.

*Alaus sericeus* Candèze 1878, Ann. Mus. Stor. nat. Genova 12: 106.

*Alaus sericeus* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 16.

*Alaus sericeus* Zwaluwenburg 1959, Pacif. Insects 1 (4): 362.

This species closely resembles the more common *Paracalais prosectus*, but its distribution is more northerly. Due to the variation in colour pattern this could not be used successfully for identification, and the only reasonably reliable external character was found to be the emarginate apices of elytra. Both angles of each emargination are mucronate, and thus easily separated from *P. prosectus* truncated apices.

The differences in genital characters, although slight, are sufficient to support the separation of *sericeus* from *prosectus*. In *sericeus* females the hoof-like chitinous structure is narrower and more rounded than in *prosectus*.

**DIMENSIONS:** Length: ♂ 19-25.5 mm, ♀ 23-30.5 mm; width: ♂ 5.5-8.5 mm, ♀ 6.5-9.5 mm.

**SPECIMENS EXAMINED:** 3 ♂, 30 ♀. AM, BM, CALIF, CSIRO, DEI, NM, QM, QU.

**DISTRIBUTION:** Queensland: Endeavour R., Cape York, Port Albany, Cooktown, Cairns, Coen, Townsville, Stanthorpe (?). Northern Territory: Darwin, Adelaide R., Humpty Do.

**TYPE DATA:** BM 'N. Holland/Rockhampton/Janson Coll.'

### ***Paracalais victoriae* (Schwarz)**

(Fig. 37-38; Pl. 46, fig. 20)

*Alaus victoriae* Schwarz 1902, Dtsch. ent. Z. 1902: 116.

*Alaus victoriae* Neboiss 1956, Mem. Nat. Mus. Vict. 22 (2): 17.

Although the type specimen has been labelled 'Victoria', it seems most unlikely that it really is a Victorian species. It was possible to match only three other specimens, all of them from Queensland. Superficially this species resembles *Para-*



*calais prosectus*, but the differently formed apex of the clytra is sufficient to separate it from this and other related species. The general colour pattern is of light ochraceous buff mottled with darker ochraceous tawny spots; mid-lateral spot on clytra narrow, equal to the width of two or three intervals only.

DESCRIPTION: Apex of the elytra truncate, the outer angle rounded; sutural carina extended to a short spine. Third interval near the base elevated to a short ridge.

DIMENSIONS: Length: 17-20 mm; width, 5-6 mm.

SPECIMENS EXAMINED: 2 ♂, 2 ♀. DEI, NM, QM.

DISTRIBUTION: Queensland: Upper Finch Hatton Ck, via Finch Hatton (Jan.), Mossman Gorge (Dec.), Canungra (Apr.).

TYPE DATA: Location DEI labelled 'Victoria/Collection Schwarz/Typus/ *Victoriae* Schw.'

***Paracalais prosectus* (Candèze)**

(Fig. 39-40; Pl. 46, fig. 21)

*Alaus prosectus* Candèze 1857, Mém. Soc. Sci. Liège 12: 236.

*Alaus immaculatus* Schwarz 1902, Dtsch. ent. Z. 1902: 115. **Syn. nov.**

*Alaus subsericeus* Schwarz 1902, Dtsch. ent. Z. 1902: 115. **Syn. nov.**

*Alaus prosectus* Neboiss 1956, Mém. Nat. Mus. Vict. 22 (2): 16.

Judging from the number of specimens available for study *Paracalais prosectus* appears to be the most common species of the genus in Australia. It is widely

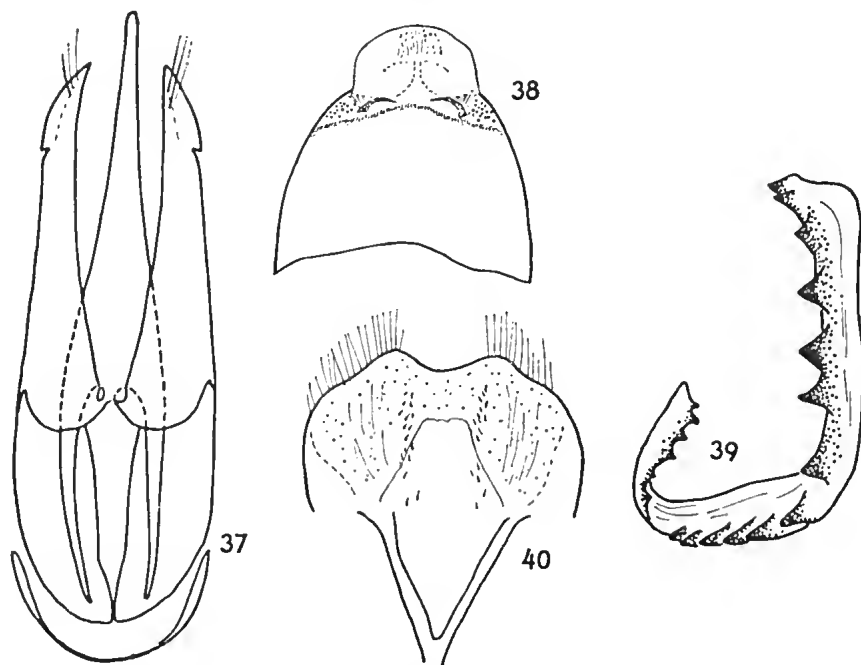


FIG. 37-40—37-38—*Paracalais victoriae* (Schwarz) Type ♂; 37—aeagus; 38—♂ 8th tergite; 39-40—*Paracalais prosectus* (Cand.); 39—chitinous collar of bursa copulatrix; 40—♀ 8th sternite.

distributed and varies considerably in size. Following the examination of types it was decided that the two species described by Schwarz, namely *immaculatus* and *subsericeus* should be regarded as synonyms. The size, colour and other characters of these two specimens fall well within the range of *prosectus* specimens.

*Paracalais prosectus* together with *P. albatu*s, *P. sericeus* and *P. spinicollis* form a closely related group, of which *spinicollis* appears to have the most northerly distribution, extending into New Guinea, *prosectus* the most southerly, being widespread in New South Wales. General colour usually varies between greyish white and yellowish white, but when greasy the specimens lose the colour pattern altogether. The scales on the ventral surface are usually more yellowish than those on dorsal.

**DESCRIPTION:** Head slightly concave anteriorly. Antennae serrate, slightly longer in males than in females, extending as far back as the front coxal cavities; last segment recessed near the apex.

Pronotum about as wide as long or slightly wider; anterior margin with a pair of small tubercles on either side of median line; posterior angles diverging, carinate.

Scutellum elongate, pentagonal, depressed and pointed posteriorly; lateral margins parallel. Elytra subparallel as far as half way, then gradually curved to the truncate apex. Third interval raised to an elongate tubercle at base. The midlateral spot varies from a distinct mark of up to three intervals width to an almost unnoticeable few dark scales. Prosternal lobe not distinctly separated, antennal groove very short; sides of mesosternal cavity slightly and gradually sloping anteriorly.

**DIMENSIONS:** Length: ♂ 21-30 mm, ♀ 20-33.5 mm; width: ♂ 6.5-9 mm, ♀ 6-10.5 mm.

**SPECIMENS EXAMINED:** 37 ♂, 100 ♀. AM, BM, CALIF, CSIRO, DEI, FH, IRSNB, MACL, MGF, NM, SAM, QM, QU.

**DISTRIBUTION:** Queensland: Gap Ck (Bloomfield R.), Goodna (Oct.), Lake Barrine (Jul.), Churchill Ck via Julatten (Nov.), Finch Hatton (Jan.), Dunwich (Stradbroke Isl.) (Apr.), Endeavour R., Mackay, Mt. Tambourine (Nov.), Biloela (Jan.), Geraldton (now Innisfail) (Nov.), Brisbane, Little Mul-Grove R., Bunya Mts. (Jan.), Kuranda (Jan.), Cairns, Mt. Molloy (Dec.), Moggill (Apr.), Middle Ridge (Jan.), Stonelands (Nov.), Clump Point (Sept.), Atherton (Dec.). A.C.T.: Canberra (Jan.). New South Wales: Dorrigo (Jan.), Sydney, Canowindra (Dec.), Tweed R. (Dec.), Rivertree, Ourimbah (Nov.), Evans Head Cabramatta (Oct.), Batemans Bay (Oct.), Rous (March). S. Australia: Nuriootpa (abraded, probably this species).

**TYPE DATA:** *Alaus prosectus* Candèze, BM; 'N. Holl. Sydney/Janson Coll. 1903-130/92/*Alaus prosectus* Type Cdz. ex Coll. de Laferte' (in Janson handwriting)/*prosectus* (Candèze handwriting). *Alaus immaculatus* Schwarz—DEI. Cotype ♀ 'N. Queensland/Coll. Schwarz/Cotypus/Genit prep. E-534 Neboiss 1966'. Cotype ♂ 'N. Queensland E. Weiske/Coll. Schwarz/Cotypus/*immaculatus* Schw.' *Alaus subsericeus* Schwarz—DEI 'N.S.Wales/Typus/Coll. Schwarz/*subsericeus* Schw.'

#### Genus *Austrocalais* gen. nov.

Type species *Austrocalais pogonodes* gen. et. sp. nov.

Although very similar to *Paracalais*, the two species referred to the new genus exhibit certain characteristics which warrant a separation at generic level.

Species of medium to moderately small size, densely covered with short, broad scales which form more or less distinct oblique lateral marking on the elytra similar to that of many species of *Paracalais*.

Head quite square, with the anterior angles elevated, centre depressed. Antennae short, second segment very short, rounded; third segment elongate, at least twice as long as second, their combined length about equal or longer than fourth; the latter and following segments flattened laterally; 11th segment elongated, oval, apex more or less distinctly truncate.

Pronotum moderately convex, lateral margins slightly depressed, posterior angles short, carinate, divergent. Prosternum narrowed posteriorly, sutures slightly curved outwards, antennal grooves present only for short distance at anterior end, levelled out to slight depression posteriorly. More or less distinct patch of beard-like hairs at anterior end of prosternum.

Scutellum elongated, pentagonal, evenly sloping forward, flat or slightly raised longitudinally in the centre, posterior end depressed, sides parallel. Elytra transversely and moderately convex, apices variable, truncate to mucronate according to species. Striae formed by a single row of punctures, intervals flat or only slightly convex, finely punctate; 3rd interval raised to short narrow ridge at base.

The 5th abdominal sternite in males truncate with row of bristles along posterior margin, 6th sternite visible and rounded. In females last visible sternite (5th) squared off in a manner similar to those in genera *Calais* and *Paracalais*, covered with modified hairs along posterior margin. Presence of humus in the pocket formed by 6th and 7th sternite similar to that on *Calais* and *Paracalais*.

Male genitalia more robust than in *Paracalais*; lateral lobes of aedeagus rounded apically, apical hooks obscure.

Walls of bursa copulatrix at the base distinctly darkened, and densely covered with minute chitinous spines. The horseshoe-like chitinous collars at the opening of colleterial glands very broad, one side being distinctly longer than the other.

#### KEY FOR SEPARATING SPECIES OF THE GENUS *Austrocalais*:

- Apex of elytra mucronate (Pl. 46, fig. 22) . . . . . *pogonodes* sp. n.  
Apex of elytra truncate (Pl. 46, fig. 23) . . . . . *aquilonaris* sp. n.

#### ***Austrocalais pogonodes* sp. nov.**

(Fig. 41-46; Pl. 46, fig. 22)

The species is easily recognized by the sharply mucronate apices of the elytra, distinct colour pattern formed by large mid-lateral markings and relatively large prothorax.

**DESCRIPTION:** Head with deep central depression forming distinctly elevated anterior angles above base of the antennae. Antennae rather short; 3rd segment about 2-3 times as long as 2nd; the following segments short and broad; last segment somewhat elongated, rounded; apex somewhat truncate, recess indistinct.

Pronotum with anterior margin somewhat scalloped; the median line elevated, more distinctly at posterior third and basal slope. Lateral margins subparallel, posterior angles short, divergent; carina short and close to lateral margin.

Scutellum pentagonal, widest at posterior third, slightly raised in the centre, posterior end depressed. Elytra about twice as long as prothorax; mid-lateral marking large, extending over seven intervals, bordered by whitish scales. Third interval raised to form elevated, more or less elongated ridge at the base; apices of the elytra individually emarginate, each angle being equally and strongly mucronate.

**DIMENSIONS:** Length: ♂ 16-20 mm, ♀ 18-24 mm; width: ♂ 5-6.5 mm, ♀ 6-7.5 mm.

**TYPE MATERIAL:** Holotype ♀ Coen, Qld. (ex F. E. Wilson collection) (NM); allotype ♂ Cape York, Qld. (NM); paratypes 8 ♀, 1 ♂; paratype ♂ N.Q. 12/24 (ex E. Sutton Coll.) (QM: T-6536); paratype ♀ Coen District, Cape York, H. Hacker; id. as *Alaus melancholicus* Cand. by Fleutiaux (DEI); paratype ♀ 'L.M.R.N.Q.\*' ex K. K. Spence Coll. id. as *Alaus pumila* by Carter (AM); paratype ♀ 'L.M.R.N.Q.' id. as *Alaus sericeus* by Carter (CSIRO); 2 paratype ♀ Coen R., Q. W. D. Dodd (SAM); paratype ♀ Cairns (MACL); paratype ♀ Coen District, Cape York, Queensland, H. Hacker (IRSNB); paratype ♀ Cairns distr. J. A. Anderson (QM: T-6535).

\* Locality 'L.M.R.N.Q.' = Little Mulgrave R., North Queensland.

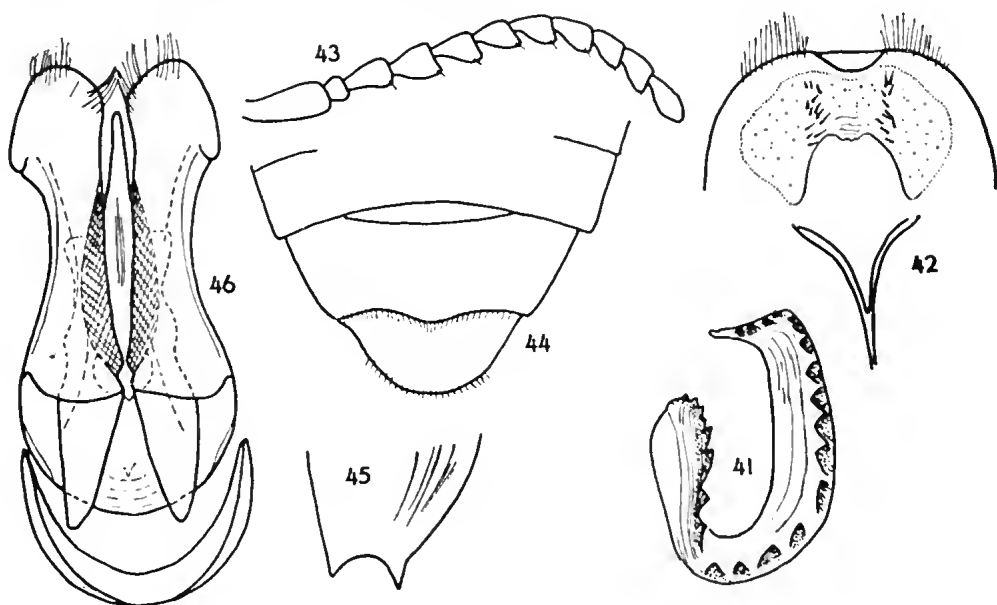


FIG. 41-46—41-46—*Austrocalais pogonodes* sp. n.; 41—Holotype ♀, chitinous collar of bursa copulatrix; 42—♀ 8th sternite; 43—♂ antenna; 44—♂ abdominal segments IV-VI; 45—apex of clytron; 46—paratype ♂ aedeagus.

**DISTRIBUTION:** North Queensland.

### *Austrocalais aquilonaris* sp. nov.

(Fig. 47-49; Pl. 46, fig. 23)

Smaller than the preceding species, and easily distinguished by the truncate elytral apices. Pattern formed by whitish (ochraceous buff) and warm, black scales as shown in Pl. 46, fig. 23.

**DESCRIPTION:** Head centrally depressed; forming an elevated angle above the antennal base; dark triangular pattern anteriorly between the base of antennae. Antennae short; third segment almost twice as long as second, their combined length exceed the length of 4th segment; 11th segment almost oval.

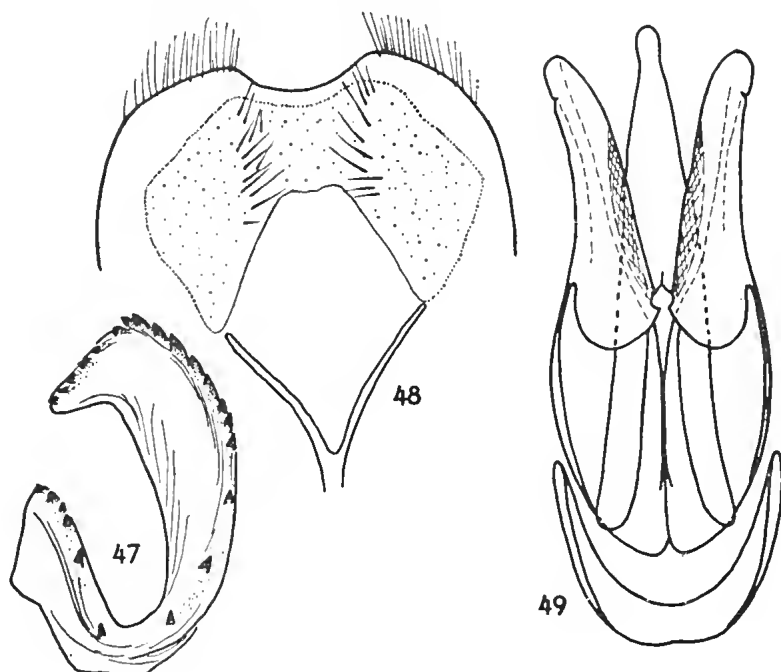


FIG. 47-49—47-49—*Austrocalais aquilonaris* sp. n.; 47—Paratype ♀ chitinous collar of bursa copulatrix; 48—♀ 8th sternite; 49—allotype ♂ aedeagus.

Pronotum with slightly elevated median line, which may be nearly absent in smaller specimens; anterior margin almost straight; posterior angles short, blunt; carina short and close to the lateral margin.

Elytra subparallel for anterior two thirds then gradually rounded towards truncate apices. Dark oblique midlateral marking bordered by line of whitish scales posteriorly. Third interval raised to elevated narrow ridge at the base.

♂ Genitalia pattern similar to that of *pogonodes* and shown in Fig. 49.

DIMENSIONS: Length: ♂ 9-14 mm; ♀ 10-14 mm; width: ♂ 2.2-4.5 mm; ♀ 3-4.5 mm.

TYPE MATERIAL: Holotype ♀ (QM: T-6531); allotype ♂ (QM: T-6532); paratypes 3 ♀ 6 ♂, all from Iron Range, Cape York Peninsula, N. Qld. 16-23 Nov. 1965, G. Monteith. 2 ♀ 4 ♂ paratypes (QU: C-148 to C-153); 1 ♀ 2 ♂ paratypes (NM).

DISTRIBUTION: North Queensland.

### Acknowledgements

The author is greatly indebted to the Institutions and private collectors for the loan of specimens and permission to study their material. Special thanks are due to Miss C. von Hayek, British Museum (Natural History), London; Dr L. Dieckmann, Deutsches Entomologisches Institut, Berlin; Dr A. Villiers, Museum National d'Histoire Naturelle, Paris, and Dr R. Damoiseau, Institut Royal des

Sciences Naturelles de Belgique, Brussels, for their valuable help and co-operation with information and loan of types.

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## Explanation of Plates

Scale: line alongside each figure indicates 5 mm.

## PLATE 43

- Fig. 1—*Paracalais gibboni* (Newm.) ♀ (NM).  
 Fig. 2—*Paracalais macleayi* (Cand.) ♀ (NM).  
 Fig. 3—*Paracalais gigas* (Cand.) ♀ (NM).  
 Fig. 4—*Paracalais nesiotis* sp. nov., Holotype ♀ (NM).  
 Fig. 5—*Paracalais lectilis* (Cand.), Holotype ♀ (IRSNB).  
 Fig. 6—*Paracalais albatrus* (Cand.), Type ♂ (MHN Paris).

## PLATE 44

- Fig. 7—*Paracalais pumilus* (Cand.) ♀ (NM).  
 Fig. 8—*Paracalais melancholicus* (Cand.) ♂ (NM).  
 Fig. 9—*Paracalais funebris* (Cand.) ♀ (QM).  
 Fig. 10—*Paracalais fornicatus* sp. nov., Paratype ♀ (NM).  
 Fig. 11—*Paracalais funereus* (Cand.), Neotype ♀ (BM).  
 Fig. 12—*Paracalais prosapius* sp. n., Holotype ♀ (AM).

## PLATE 45

- Fig. 13—*Paracalais darwini* (Blkb.), Holotype ♂ (BM).  
 Fig. 14—*Paracalais murinus* sp. nov., Holotype ♀ (NSWDA).  
 Fig. 15—*Paracalais suboculatus* (Cand.) ♀ (NM).  
 Fig. 16—*Paracalais hayekae* sp. nov., Holotype ♀ (NM).  
 Fig. 17—*Paracalais spinicollis* (Zwal.) ♀ (QM).  
 Fig. 18—*Paracalais sericeus* (Cand.) ♀ (BM).

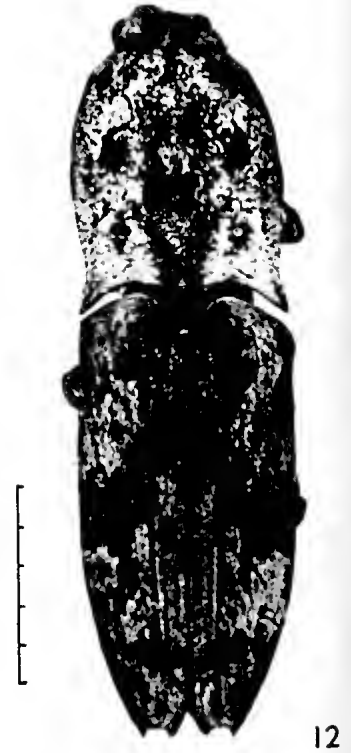
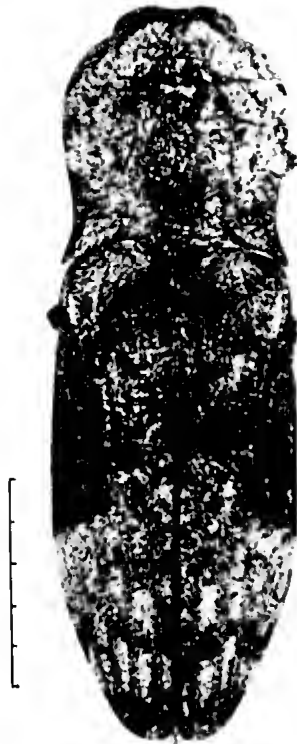
## PLATE 46

- Fig. 19—*Paracalais spiciformis* sp. n., Holotype ♀ (SAM).  
 Fig. 20—*Paracalais victoriae* (Schw.), Type (DEI).  
 Fig. 21—*Paracalais prosectus* (Cand.) ♀ (BM).  
 Fig. 22—*Austrocalais pogonodes* sp. nov., Paratype ♀ (AM).  
 Fig. 23—*Austrocalais aquilonaris* sp. nov., Holotype (QM).  
 Fig. 24—*Calais excavatus* Fab. ♀ (NM).











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## AUSTRALIAN ABORIGINAL REMAINS ~ 5,540 YEARS OLD, FROM MITIAMO, VICTORIA, AUSTRALIA

By E. D. GILL

National Museum of Victoria

### Abstract

On a granite pediment, under 5-6 ft. of granitic detritus, human bones c. 5540 years old were found at Mitiamo, N. Victoria, in a zone of minor carbonate deposition. The date gives an indication of the rate of deposition of detritus, and suggests alternate phases of detritus accumulation and dispersion.

### Site

In northern Victoria a range of granitic hills (Terricks Range) runs north from Mitiamo to Mt. Hope (Gregory 1903: 89-92; Hills 1941). NE of Mt. Hope is Kow Swamp where the Cohuna Cranium was found (Macintosh 1952 a, b, 1953). On the southern end of this range in the Shire of Gordon is the Mologa State Forest, a dry sclerophyll forest growing on porphyritic granite (Fig. 1). In the north-east sector of this forest is a sand pit where the Mitiamo Skeleton was found. Sandy sediment, derived by mechanical weathering of the granite (Hills 1940: 21) forms a talus apron resting on a platform (pediment) of granite. Front-end loaders dig out this detritus for road works. During this operation, the Mitiamo Skeleton was found. The site is on the N. side of an EW. ridge jutting out from the main mass of the granite ( $144^{\circ} 10' \text{ E.}$ ,  $36^{\circ} 8' \text{ S.}$ ).

### Discovery

Mr John A. Mitchell, headmaster of the Boort High School, having learnt from Valma and Glenda Smith that bones had been found in the excavation, sent some pieces to the National Museum in Melbourne. They belonged to an adult aborigine. The front-end loader completely broke up the skeleton, and various pieces were souvenired. An attempt to secure more of the skeleton was unsuccessful. Under the guidance of Mr Mitchell, I visited the site in August 1964, and concluded that the skeleton was a burial covered by later sediment, and so a fossil. Geological evidence suggested a mid-Holocene age, and a radio-carbon date was obtained to provide information of geomorphic and geologic as well as anthropologic value.

### Geology

Lichens grow on the surface of the coarse granite, and trees send down roots into the major joint planes, while herbaceous plants flourish in sheltered places where soil accumulates and water seepages occur. Probably as a result of the steep temperature gradients established, the granite tends to lift in concentric shells. The rainfall averages approximately  $15\frac{1}{2}$  in. (40 cm) per annum.

The granite debris forming the talus apron consists of an unsorted silty sand with mostly angular grains. It varies from red to reddish-brown throughout its depth. There were 5-6 ft (1.5-1.8 m) of sediment where the skeleton was found  $3\frac{1}{2}$  chains (70 m) from the granite hill (Fig. 2). Nearby an island of sediment was left because of a large tree growing on it, and this gave the original depth of sediment at that point, viz. 8-9 ft (2.4-2.7 m).

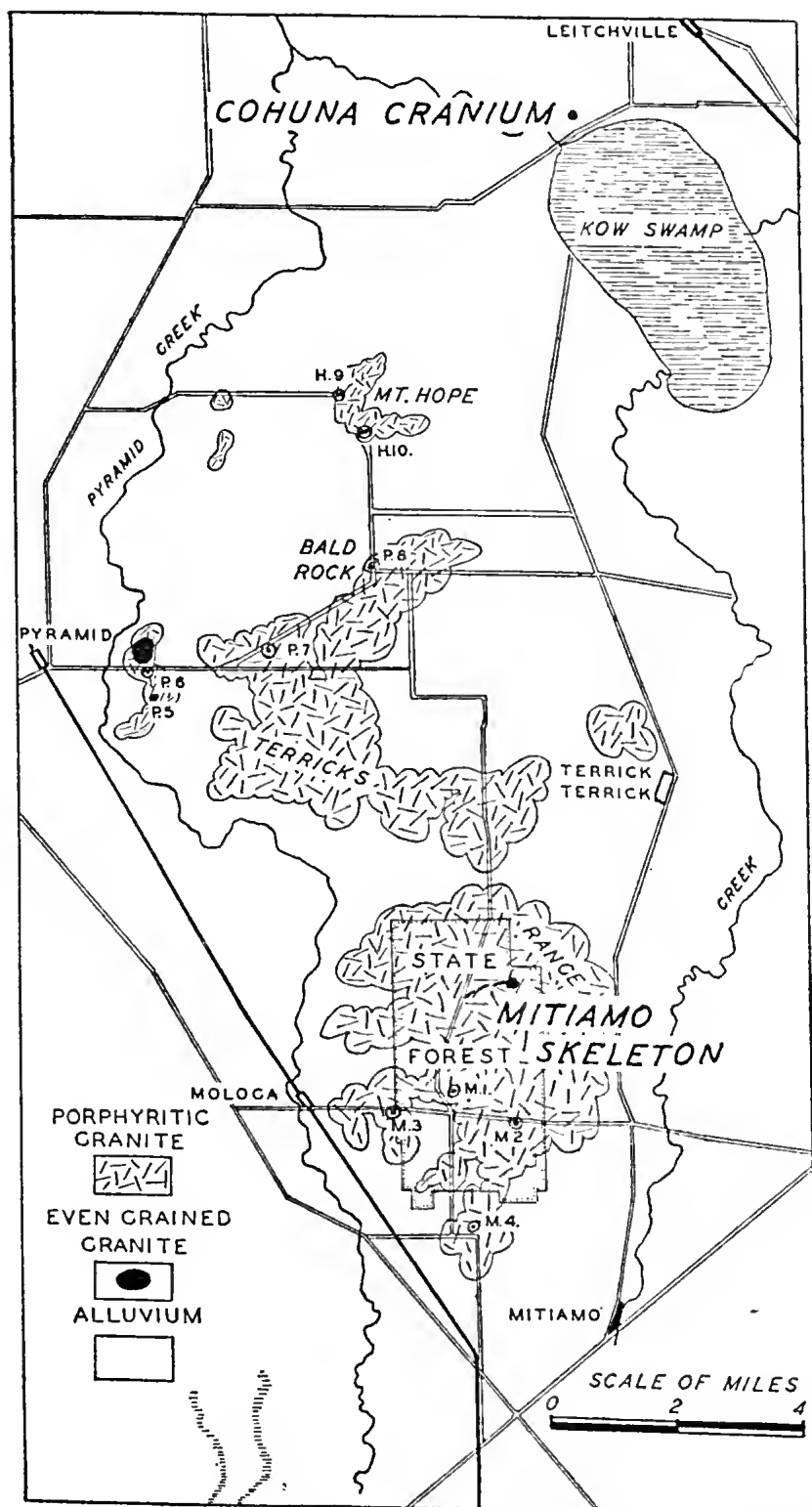


FIG. 1—Localities from which were obtained the Mitiamo Skeleton and the Cohuna Cranium. Base map after Hills 1941.

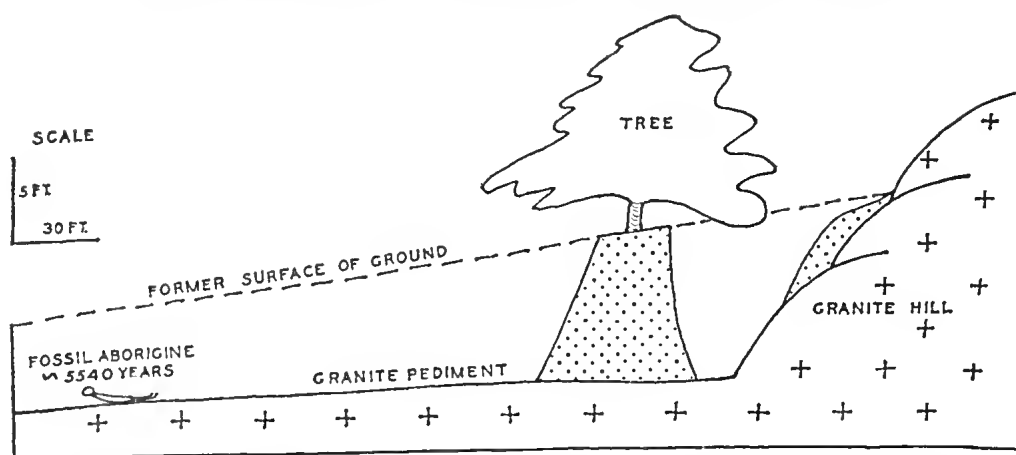


FIG. 2—Mitiamo Man site in the Mologa Forest, North Victoria, showing the apron of granitic detritus overlying a granite pediment. The skeleton was 5-6 ft from the surface and has a radiocarbon age of 5,540 years B.P. The symbol of the skeleton is not drawn to scale.

Some sediment remains against the granite hill where it could not be excavated by the front-end loader, and this shows it was 10-11 ft (3-3.3 m) deep at that place. The sediments are firm but not strongly compacted. The numerous excavations for sand in this area show clearly the general structure of a siliceous talus apron on a granite pediment.

### Mitiamo Skeleton

The statements of the workmen, and the evidence of such bone fragments as were collected, suggest that there was originally a complete skeleton. As far as can be determined, the limbs were not flexed, but the skeleton was in a half-sitting position facing S. Australian aborigines in this area used to bury their dead in shallow graves and so to find this skeleton at 5-6 ft (1.5-1.8 m) depth meant that the aborigine was buried when the surface of the ground was not far above the pediment. The remaining depth has built up since burial. Under the present geomorphic conditions, one cannot see how water could strip the overlying deposits off the pediments, and so such a process probably occurred as a result of wind erosion, which would imply a drier time than the present. Such a drier time occurred during the mid-Holocene (Gill 1953, 1965). If the pediment were then largely stripped, one would expect the same to have happened in previous dry periods. Thus through the Pleistocene, there may well have been alternate building up of the talus apron and subsequent stripping. In the dry periods the creeks would be ephemeral, and the windblown saltatory material would migrate to the low areas of the terrain, filling stream channels, which would be excavated again in the wet periods.

The discoverers (Mr K. Gladman and Mr E. L. Smith) stated that the skeleton was 'set in a very hard type of granitic sand'. The hardness was probably due to secondary carbonates. One fragment of the cranium 1 cm thick that has been preserved has secondary carbonate on it (P24685 Nat. Mus. Vict.); all the bones did not have this. Such local accumulations of carbonate are found at the base of the sediments. Skeletal fragments (cranial and postcranial) were sent for radio-



carbon dating after examination by an anatomist. Their age so obtained was  $5,540 \pm 200$  years B.P. (Gak-705). The organic materials in the bones that were extractable by hot acid solution were used for the dating.

### Osteology

Professor N. W. G. Macintosh kindly examined the fragments and commented on them as follows: 'Humerus, radius, femur are represented by fragments which are sufficiently large to permit one to say no bowing had occurred; innominate bone and a rib are also represented by fragments; the cortical bone of the femoral fragment appears to be markedly porous, relative to the other fragments; an odd feature is seen in the external concavity of the left squamous part of the frontal bone. I have not seen such a degree of reverse curvature even in cases of artificial skull deformation. I recommend that you have these fragments examined by a pathologist.'

The bones were examined by Dr Hurley of the Department of Pathology of the University of Melbourne, who kindly made and examined sections of a part of the cranium, and reported that no abnormality was observed in these sections. The curious deformity of the left frontal bone therefore remains unexplained. The internal surface of the bone is not indented parallel to the outside surface; the curvature does not appear to be due to a blow.

### Aborigines in the Mid-Holocene

The evidence for a mid-Holocene higher temperature in SE. Australia is widespread (Gill 1953, 1955, 1965; Bowler 1963). An indication of the time of onset of these conditions is provided at Lake Weeranganuek in Western Victoria where fossiliferous lacustrine sediments pass up into windblown parna dunes. Bones from the layer immediately under the parna gave a date (GX-0152) of  $6,435 \pm 110$  (Gill 1964). The time of passing of these conditions is indicated by the stabilization of a terrain at Port Campbell that had been deflated during the mid-Holocene. Grasstree resin rings mark this time of stabilization, and one of these gave a date (W-1477) of  $3,880 \pm 250$  years B.P. (Gill 1965). These datings are only a beginning but they at least show (with other dates) that there was a rise in mean temperature at this time in Victoria (as there was in many other parts of the world) leading in Victoria to drier conditions with drying up of lakes and increased soil erosion.

No definable artifacts were discovered at Mitiamo. The Colongulac Skeleton (Gill 1953) belongs to the mid-Holocene occurring in a parna dune such as were commonly built up on the shores of shallow lakes in northern and western Victoria as a result of their frequent desiccation. At Mitiamo and in similar situations talus aprons were built up as high or higher during the Last Glacial but during the dry period they were dispersed, only to build up again in the following wetter period. Since the mid-Holocene drier period the talus apron has built up at a mean rate of one foot or less per 1,000 years. Soil formation has continued all this time, so this is one reason why the profile is red throughout.

### Conclusions

1. The Mitiamo Skeleton is of an adult aborigine who lived in northern Victoria during the mid-Holocene ( $\sim 5,540$  y. B.P.).
2. The talus apron present above the skeleton was largely absent in the mid-Holocene, there being only a thin layer of sand over the granite pediment. In this the Mitiamo skeleton was buried. The terrain was then relatively unstable,



and the talus has since built up at the mean rate of one foot or less per 1,000 years. This accounts for the juvenility of the soil.

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## RESEARCHES ON THE EARTH'S INTERIOR\*

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**Abstract**

An account is given of the derivation of the distributions of density, pressure, gravitational intensity, incompressibility and rigidity in the Earth's interior. Evidence on the solidity of the inner core is presented. Reference is made to the internal structures of the terrestrial planets and to a theory of the origin of the Moon. Attention is given to some questions of scientific inference.

This is a great occasion for me. As some of you will know, I once had the privilege of being a Victorian resident for several years. Those years were among the most pleasant of my academic life, and, Sydney's rugged charms notwithstanding, I still look back to my time in Victoria with fond memories. The award of this handsome Research Medal of the Royal Society of Victoria therefore means even more to me than the very great honour it confers.

The principal field of my research has been in what is nowadays called theoretical solid-Earth geophysics. The adjective 'solid-Earth' means the Earth from the surface downward and is used to distinguish that part of the Earth from the atmosphere and regions above. The fact that some of the 'solid Earth' happens to be fluid has not worried the inventors of the term. For the most part, my work has been concerned with the mechanical and elastic properties of the Earth's deeper interior, and that will be my central topic tonight.

I shall also be saying a little about my work on the Moon and some of the other planets. Strange as it may seem, this also comes under the heading of solid-Earth geophysics, the reason being that the internal structures of the Earth and other planets are likely to be intimately related. Even before artificial satellites became subjects of serious conversation, geophysicists had been interested in planetary interiors. With satellites now starting to gather direct observations on planets, the interest has lately been intensified.

My approach to my subject is as an applied mathematician, and I shall try, here and there, to give some glimpses of the type of thinking an applied mathematician brings to bear in his research. That does not mean that I shall be attempting to use any serious mathematics this evening. While formal mathematics is of course normally involved in applied mathematical work, applied mathematics is far from being the same subject as pure mathematics. An applied mathematician has, first and foremost, to be context-minded, and pays attention to questions of inductive as well as deductive inference. Theoretical geophysics is an unusually good field to exhibit the applied mathematical approach, and I hope you will not mind if, in addition to relating some specific results of my work, I attempt to show something of the underlying philosophy of the methods used.

I shall first talk about the Earth's interior generally, as a preliminary to showing where my own contributions fit.

\* Lecture delivered following the presentation to Professor Bullen of The 1965 Research Medal.

### Mean Density and Moment of Inertia

It first became possible to make inferences about the interior of the Earth when the shape, size and mass became determined to reasonable precision. By 1798, Cavendish had obtained a value near  $5\frac{1}{2}$  g/cm<sup>3</sup> for the Earth's mean density. This showed that the material of the Earth's deeper interior must be at least twice as dense as the average surface rock.

The inferences were carried further during last century when the Earth's moment of inertia was determined. The moment of inertia of a body is connected with the internal distribution of mass. For a sphere of constant density, the moment of inertia  $I$  about a diameter is  $0.4 MR^2$ , where  $M$  and  $R$  are the mass and radius. For a body like the Earth, where the density must (essentially) increase with depth, knowledge of the amount by which the coefficient is less than 0.4 contributes to knowledge of the degree of central concentration of mass in the body.

A variety of evidence is used in determining the value of the coefficient for the Earth. As the Earth rotates in the gravitational fields of the Sun and Moon, the Earth's equatorial bulge causes the axis of rotation to precess. The axis describes a cone relative to the distant stars, and the effect reveals itself in an observed motion of certain points (the equinoctial points) around the celestial equator, at a rate just over 50 seconds of arc per year. The phenomenon is called the precession of the equinoxes, and observations of it contribute to the determination of  $I$ . Further information on  $I$  comes from the theory of the figure of the Earth, in conjunction with knowledge of the surface gravity and speed of axial rotation.

In this way, it was found last century that  $I = zMR^2$ , where  $z$  lies between 0.33 and 0.34. This result confirmed the presence of a substantial increase of density with depth in the Earth, and indicated the order of magnitude of the central concentration. Within the last few years, observations of the orbits of artificial satellites have supplied more precise information on  $I$ , and the coefficient  $z$  is now estimated to lie between 0.330 and 0.331.

### Evidence from Seismology

Any picture of the Earth's internal structure must agree with the known values of the mass, radius and moment of inertia. But there are many possible distributions of mass compatible with these values. To narrow the possibilities requires evidence from fresh sources. The outstanding source of new evidence has been seismology, the study of earthquakes, through which it has become possible to obtain numerical values of certain mechanical properties at specific points throughout the Earth. Through seismology, it has become possible to chart out the structure of the Earth in considerable detail.

With scientific detachment, I shall look upon earthquakes as useful generators of seismic waves, passing over the fact that some of the most 'useful' earthquakes have been among the most disastrous to mankind. Every year there occur many earthquakes large enough to send detectable waves through all parts of the Earth's interior. The waves, on emerging at the surface, are recorded by seismographs in practically all countries of the world. The records, or seismograms, provide the basic observational material from which the seismologist works. In a sense, seismology can be looked upon as a branch of communication theory. An earthquake conveys to receivers at the surface information on the nether regions its waves have traversed. It writes its information on the world's seismograms, and a task of the seismologist is to decode the writing.

The first requirement in the decoding process is a reliable theory of seismic wave transmission. The waves are of the nature of mechanical vibrations. As they

pass through the Earth, they involve to-and-fro motion of particles, and thus deformational motion inside the Earth. So what is required is a suitable theory on the deformation of the internal material of the Earth—a theory on the inter-relation of stress and strain.

### Elasticity Theory

A typical question of scientific method now enters. Experiments have shown that the relatively simple mathematical theory of perfect elasticity, a generalization of Hooke's law, gives a useful description of the observed elastic behaviour of many solids and fluids subjected to stress under ordinary laboratory conditions.

A characteristic of perfect elasticity in its simplest form is that, for a given material under given thermodynamical conditions, the stress-strain relations are entirely determined by knowledge of just two coefficients, which may be suitably taken as the 'incompressibility' or 'bulk-modulus', and the 'rigidity'. The incompressibility specifies the capacity of the material to resist a symmetrical pressure; rigidity, the capacity to resist stresses tending to change the shape. Perfectly elastic materials are classified into solids and liquids according to the magnitude of the rigidity. In ordinary conditions, a solid has considerable incompressibility and rigidity (of the order of  $10^{11}$  dyn/cm<sup>2</sup> or more) while a fluid has negligible rigidity. Thus, for example, a fluid can readily change its shape to fit a containing vessel.

The equations of perfect elasticity, like all equations and so-called laws in natural philosophy, are mathematical models which could apply with total precision only to ideal materials. The utility of any mathematical model is gauged by its degree of simplicity and its compatibility with the relevant observations. The question arises as to the suitability of the perfect elasticity model for the unknown materials of the deep interior of the Earth. Because of its comparative simplicity and its degree of success with laboratory materials, it is appropriate to take this model as a trial for the Earth, to be modified of course should subsequent testing against observations reveal discrepancies. It transpires that the perfect elasticity model is a remarkably good one where seismic observations are concerned, and, in particular, is quite adequate for the principal conclusions I shall be drawing tonight.

As a result of this adequacy, it is permissible to speak of solid and fluid regions of the Earth's interior. This needs stressing because of unnecessary arguments that have sometimes arisen between geologists and applied mathematicians on the point. Geologists and others have, in particular, questioned the use of terms such as solid and fluid where pressures are as high as they are in the Earth's deep interior. But the scientific approach to the description of properties in the Earth is really no different from that for materials in the laboratory. In both cases, a material is called solid or fluid according to the values, large or small, of coefficients which appear in trial equations used to describe the elasticity. The only difference in practice is the irrelevant one of the technique used in finding the values of the coefficients. For materials in the laboratory, the technique is to match the equations against fairly direct laboratory measurements of stress and strain, and for the Earth's interior, to match them against seismic and related observations.

One caution needs, however, to be stated. The periods associated with seismic wave motion do not exceed the order of an hour, and it cannot be asserted from the seismic observations that the perfect elasticity model is adequate in contexts where much longer periods are involved, for example, periods on the geological time scale. More than two coefficients may then be needed in expressing the stress-strain relations, and a simple classification into solid and fluid may not then be

justified. Thus it needs to be appreciated that my use of the terms solid and fluid is part of a description of the essential response of the Earth to comparatively short-lived stresses. I have gone into a little detail on this question, since a section of my research is concerned with the solidity or fluidity of the Earth's deep interior—in the sense just defined.

### Seismic Travel-Time Tables

Next for a little detail on the transmission of seismic waves. The perfect elasticity model being accepted as suitable for the context, it can be deduced that the Earth can transmit two types of waves through its interior. These are the 'primary' or  $P$  waves, and the 'secondary' or  $S$  waves. The speeds of travel,  $\alpha$  and  $\beta$ , of the  $P$  and  $S$  waves at any point  $Q$  are given by

$$\alpha^2 = (k + 4\mu/3)/\rho, \quad \beta^2 = \mu/\rho \quad (1)$$

where  $\rho$ ,  $k$  and  $\mu$  denote the density, incompressibility and rigidity of the material at  $Q$ .

The  $P$  waves are like sound waves and cause the particles of the medium to vibrate in the line of wave advance. The  $S$  waves, which travel more slowly, cause the particles to vibrate sideways. The  $P$  waves travel through solids about  $1\frac{1}{2}$  times as fast as  $S$  waves, while  $S$  waves, which depend crucially on the rigidity, do not travel through fluids. Thus detection of  $P$  and  $S$  waves in an internal region of the Earth is evidence of solidity. Failure to detect  $S$  waves suggests fluidity. Near the Earth's surface,  $P$  waves travel at about 5 km/sec and  $S$  waves at about 3 km/sec. The speed of  $P$  waves reaches its maximum of  $13\frac{1}{2}$  km/sec at a depth of 2,900 km below the surface.

In 1897,  $P$  and  $S$  waves were identified on seismograms by the Englishman R. D. Oldham. This supplied the first check on the suitability of the perfect elasticity theory for seismic wave transmission in the deep interior of the Earth.

Soon after Oldham's discovery, efforts were put into obtaining tables for the travel times of seismic waves between an earthquake focus and points of the Earth's surface where the waves are recorded. The energy in the waves can, to good approximation, be treated as travelling out along rays analogous to rays of light. This is a consequence of certain common features in the mathematics underlying the transmission of optical and seismic waves. In general, the ray theory is very accurate in localities not too close to the focus.

Seismic rays are reflected or refracted in accordance with a law that is a generalization of Snell's law. When a  $P$  or an  $S$  ray meets a surface of discontinuity in the Earth, it may be reflected and refracted into both  $P$  and  $S$  rays. This multiplicity of derived rays means that seismograms usually show many 'phases', each phase corresponding to the arrival of a group of waves by one of many types of path. Between surfaces of discontinuity the rays are generally curved. This is because the seismic velocities  $\alpha$  and  $\beta$  change continuously with depth as  $\rho$ ,  $k$  and  $\mu$  change.

The evolution of travel-time tables involves sorting out the many phases on the tangled seismic records, with the help of the basic elasticity theory, wave theory and statistical theory. The task is complicated, among other things, by ignorance of the origin time and source location of every natural earthquake used for the purpose.

At the time when I entered seismology, in 1931, much work had previously been done on travel-time tables, but it was suspected that the tables still contained large errors. The grounds for suspicion were fairly strong. With some particular

earthquakes, for example, calculations based on the existing travel-time tables in fact gave what were euphemistically called 'high foci'—some of the computed foci were 100 to 200 km above the Earth's surface. It was my good fortune to meet Sir Harold Jeffreys of Cambridge at a time when he had decided that a comprehensive revision of the tables was necessary, and between 1931 and 1939 he and I spent a good part of our research energy working jointly on the problem. By 1939, we had managed to reduce the table errors from the order of a minute, in travel times up to 20 minutes and more, to the order of a small number of seconds. We were not the only workers on the problem. Gutenberg and Richter in California also spent some years seeking to improve the travel times, and their results agreed with ours within the claimed accuracy. Since 1940, the tables of Jeffreys and myself, called the J.-B. tables, have been used in preparing the International Seismological Summary.

### Use of Nuclear Explosions

Finer accuracy in travel times is now being obtained through the use of nuclear explosions, which are also generators of seismic waves. Moreover, in spite of being smaller than large natural earthquakes, they have the cardinal advantage of providing controlled experiments in which the location of the focus and the time of origin can be precisely known.

In 1957, the late T. N. Burke-Gaffney of Riverview Observatory, Sydney, and myself brought a degree of notoriety upon ourselves by estimating, for four American hydrogen bomb explosions, origin times which, when the source data were later released, proved to be correct to 0.0, 0.4, 0.7, and 0.1 second, respectively. From that time, the United States has released source details on most American nuclear explosions, with much advantage to the science of seismology.

Comprehensive corrections to the J.-B. tables have, however, not yet been evolved, and the tables continue to be widely used. This is partly because of severe restrictions on the locations of nuclear explosions to date.

The travel-time tables provide the most precisely determined evidence available on the structure of the Earth's interior. An early result was the fairly high degree of independence of the travel times on geographical region, showing that, to a strong first approximation, the matter in the Earth is symmetrically distributed about the centre. The biggest deviation is that due to the Earth's oblateness. Jeffreys and I were able to show, incidentally, that from seismic data alone we could estimate the Earth's ellipticity of figure within an error of order one-sixth. Other deviations affecting the travel times are connected with the Earth's major geographical features and may possibly be significant down to a few hundred km below the surface.

With spherical symmetry established as a serviceable first approximation, it becomes possible by mathematical processes to infer the values of the seismic velocities  $\alpha$  and  $\beta$  in terms of the distance  $r$  from the Earth's centre. The Earth can then be divided into a number of internal regions according to depth. Boundaries are taken where  $\alpha$  and  $\beta$  or their gradients show sudden changes with respect to  $r$ .

Further, when the values of  $\alpha$  and  $\beta$  are known, the equation (1) shows that the quantities  $k/\rho$  and  $\mu/\rho$  are known. In this way, seismology has provided fairly direct information on these quantities throughout much of the Earth's interior.

Some of the main boundaries below the Earth's surface had been located long before the work on travel times had reached its present degree of precision.

### The Earth's Crust, Mantle and Core

In 1909, A. Mohorovičić, a Balkan seismologist, located a boundary some tens of kilometres below the Earth's surface in his region. Others later showed this boundary, now called the Mohorovičić discontinuity, to be world-wide. It is characterized by a marked jump in the  $P$  and  $S$  velocities about 35 km below the surface in continental shield areas, is somewhat deeper under some mountain ranges, and shallower under the main ocean floors. The name Mohole has been given to a project to bore a hole down to and through the Mohorovičić discontinuity. In 1957, I happened to be chairman of a meeting in Toronto at which the proposal was first sponsored by the International Association of Seismology. The idea is to obtain samples of materials all the way down to the discontinuity and of the material immediately below, and so provide a useful check on a section of seismological and other inferences.

The region between the Earth's surface and the Mohorovičić discontinuity is nowadays conventionally called 'crust'.

Another early seismological result was Gutenberg's location in 1914 of a major discontinuity at a depth near 2,900 km below the surface. This boundary separates what has come to be called the Earth's 'mantle', on the upper side, from the 'central core' below.

Both  $P$  and  $S$  waves are recorded throughout the mantle, showing that the mantle is solid in the sense that I have defined. Further, the rigidity steadily increases with depth throughout nearly all the mantle. A century ago, Kelvin had shown that, contrary to the prevailing view that the Earth is mostly molten below the crust, the average rigidity of the whole Earth exceeds that of ordinary steel. Kelvin's inference was based on astronomical measurements of movements of the Earth's poles and measurements of the tidal deformation of the solid Earth. Kelvin's general conclusion is now amply confirmed with the addition of evidence from seismology. My own calculations give steadily increasing values for the rigidity throughout most of the mantle and a value at the bottom of the mantle between three and four times that of ordinary steel.

This last result, taken in conjunction with modern evidence of the type used by Kelvin, in fact leaves little room for any rigidity in the central core. The Japanese geophysicist Takeuchi in 1950 and the Russian Molodenski in 1955, as a result of very arduous calculations, showed from the overall evidence that the average rigidity below the mantle can at most be a small fraction of the value in the mantle. Their work confirmed, what had been long suspected, that most of the central core is in a fluid or molten state. The result is in line with the failure of seismologists ever to detect  $S$  seismic waves in the core.

### The Earth's Inner Core

An important discovery was made in 1936 by the Danish woman seismologist, Inge Lehmann. Using European records of two New Zealand earthquakes and some other evidence, she inferred the existence, deep down in the Earth's central core, of an inner core characterized by a marked jump in the seismic  $P$  velocity. The inner core is comparatively small, with radius about 1,200 km. For want of a better name, the part of the old 'central core' outside the inner core has been called the 'outer core'. The outer core is almost certainly molten, but I shall later give reasons which have led me to think that the inner core is probably solid. (The calculations on the small average rigidity of the central core are not fine enough to enable a conclusion to be drawn about the fluidity or rigidity of the inner core, which occupies only about 1 per cent of the whole core volume.)



A broad picture of the interior of the Earth as revealed by seismology is thus: a thin crust at the surface; a solid mantle extending downward for 2,900 km; a fluid outer core, some 2,200 km thick; and then the inner core, probably solid, occupying the remaining 1,200 km to the centre.

### The Earth's Density Distribution

I shall now say something about my work on the Earth's density and related properties. This has been my longest-sustained interest, and started in 1935 at the time when I was working with Jeffreys on the travel-time tables. We had then reached the point where it became necessary to take note of the effect of the Earth's oblateness on the seismic travel times, and I undertook to estimate the necessary allowances.

It turned out that this was not merely a matter of allowing for extra lengths of path where rays extend through the Earth's equatorial bulge, or for reduced lengths due to the flattening of the Earth in high latitudes. The paths are also affected along their entire length by the ellipticities of internal surfaces of constant density. Before the effects could be calculated it was necessary to know these internal ellipticities to adequate precision. This in turn depended on knowledge of the internal distribution of density in the Earth, and I soon found that the existing density results were far from being reliable enough for my purpose. Thus in 1935 I stopped my other work for a time and set about trying to obtain reliable details on the Earth's density.

There was available a differential equation for the density gradient at points of the Earth's interior, first used, in 1923, by the Americans Williamson and Adams. This equation utilizes the fact that knowledge of the  $P$  and  $S$  seismic velocities at any depth in the Earth gives knowledge of  $k/\rho$  at that depth. On the perfect elasticity theory,  $k/\rho$  gives the ratio of the pressure gradient to the density gradient for a material of uniform composition. In this way it is possible to make some progress towards evaluating density gradients in the Earth.

Prior to 1936, the Williamson-Adams equation had been used by a number of authors in seeking to work out the variation of density in parts of the Earth. But the equation involves a number of assumptions outside the seismic evidence, and widely different values of the density distribution had been obtained. It was my good fortune to stumble across a method which appeared to yield precisely determined values for the first time.

I assumed a value near  $3.3 \text{ g/cm}^3$  for the density just below the Earth's crust and applied the Williamson-Adams equation, in conjunction with the then available seismic data, to obtain a trial density distribution for the mantle. I then applied a test which had not been previously used. This was to work out the consequent value of the moment of inertia of the core. On the basis of my trial density solution for the mantle, I computed the moment of inertia of the mantle and subtracted this from the known moment of inertia of the whole Earth. The result gave  $0.57 ma^2$ , where  $m$  and  $a$  are the mass and the radius of the core. Now the coefficient 0.57, being substantially in excess of 0.40, would require the core to be much denser near the outside than near the centre, a conclusion that has to be rejected on grounds of the Earth's stability.

It followed that the procedure in obtaining the trial density distribution for the mantle was somewhere seriously in error. After exhausting the possibilities I was able to show that the weak point was that, over a sizable range of depth, the Williamson-Adams equation is unreliable in respect to the assumption of uniform composition. I found that I had provided evidence that there exists inside the

mantle a substantial variation of chemical composition, or, alternatively, substantial phase changes.

Further, by making the necessary modifications to my approach, and bringing the moment of inertia test to bear, I was able to obtain what seemed, after all tests had been made, fairly narrowly determined values of the density  $\rho$  down to a depth of nearly 5,000 km below the surface, that is, down to near the inner core boundary. The details of the calculation are fairly complicated, and had to be revised when the  $P$  and  $S$  velocities came to be better determined from the J.-B. tables. I shall here give only the broad results.

According to these, the density varies from 3.3 just below the crust to  $5\frac{1}{2}$  g/cm<sup>3</sup> at the bottom of the mantle. The density then jumps to  $9\frac{1}{2}$  at the top of the outer core, and reaches  $11\frac{1}{2}$  to 12 g/cm<sup>3</sup> near the inner core boundary. The results appeared to be accurate within 2-3 per cent throughout the mantle and 5 per cent in the outer core, and this estimate of the uncertainties still stands.

I was also able to show that the density at the Earth's centre must be at least 12.3 g/cm<sup>3</sup>, but was not able to make a positive estimate of the density in the inner core until much later. In 1942, I worked out several Earth models taking different arbitrary values for the central density. Two of these models continue to be of interest. In one of them, the central density has the minimum value of 12.3 g/cm<sup>3</sup>; in another, it is 17.3 g/cm<sup>3</sup>. Because the inner core is so small, there is not much difference between the models outside the inner core.

### Pressure, Gravity, Incompressibility, Rigidity

The work on density carried with it a crop of results on other properties, including values for the pressure, gravitational intensity, incompressibility and rigidity, throughout most of the Earth.

I was able to show that the pressure reaches about  $1\frac{1}{2}$  million atmospheres at the bottom of the mantle, and between  $3\frac{1}{2}$  and 4 million atmospheres at the Earth's centre. I found the value of  $g$  (gravitational attraction) to stay within 1 per cent of 990 cm/sec<sup>2</sup> down to a depth of 2,400 km, rising to a maximum of about 1,050 cm/sec<sup>2</sup> at the mantle-core boundary, and then dropping steadily to reach zero at the Earth's centre.

The rigidity values rose fairly steadily with depth in the mantle, reaching about  $3 \times 10^{12}$  dyn/cm<sup>2</sup> at the bottom, then dropping below measurable limits inside the outer core.

The incompressibility values in general rose steadily throughout the Earth, to  $14 \times 10^{12}$  dyn/cm<sup>2</sup> or more at the centre.

### Confirmation from Chilean Earthquake

In 1960, there was unexpected confirmation of the essential numerical results in this set of calculations. In May of that year, there occurred in Chile a very great earthquake which excited fundamental vibrations of the whole Earth, sufficiently large to be clearly recorded in several parts of the world. There was a spectrum of fundamental and overtone periods, ranging from nearly an hour downwards, and providing invaluable new observational material on the structure of the Earth's interior.

It is possible, by heavy mathematical labour, to calculate the periods of these vibrations for any Earth model, given the distributions of density, incompressibility and rigidity. Such calculations had been carried out for a number of Earth models, including mine, by C. L. Pekeris of Israel. The results showed that the new

observations could be fitted only by models which agreed with mine within the stated uncertainties.

Efforts have since been made to use the Chilean observations to add precision to results on the Earth's density. Some small modifications have been suggested inside the Earth's mantle, but the new method has not yet gone very far beyond providing valuable confirmation of the earlier results.

### Solidity of Inner Core

I return now to my calculations on the incompressibility  $k$ . In the region consisting of the lower mantle and outer core together. I found that  $k$  varies much more smoothly than either the density or rigidity, both of which have large changes at the mantle-core boundary. When I looked into physical aspects of the behaviour of  $k$ , I found reason to propose, in 1946, as a trial hypothesis, that  $k$  varies smoothly with the pressure  $p$  throughout the whole Earth from the middle of the mantle to the centre of the core.

It was this development which led me to infer that the Earth's inner core is probably solid. Stripped of complications, the argument is essentially as follows. Miss Lehmann had shown that  $\alpha$  jumps in value from the outer to the inner core. By (1),

$$\rho\alpha^2 = k + 4\mu/3. \quad (2)$$

Almost certainly,  $\rho$  does not decrease significantly with depth. In view of the evidence that  $k$  varies smoothly, I then interpreted the jump in  $\alpha$  as due to a jump in  $\mu$  rather than  $k$ . Since  $\mu$  is effectively zero in the outer core, I thus inferred that there is probably a change from the molten to the solid state at the inner core boundary.

During the following twenty years, I have had to adapt my theory on compressibility to meet later evidence from experimental and theoretical physics. But the key result still remains that it is very improbable that  $k$  could jump sufficiently at the inner core boundary to account for the seismic observations. Although direct evidence has not yet been obtained, it thus remains strongly probable that the inner core is solid. In the last few years I have obtained new evidence which I shall mention shortly.

### The Earth's Central Density

It was through the theory on compressibility that I was also able, in 1950, to make a tentative estimate of 18 g/cm<sup>3</sup> for the Earth's central density  $\rho_0$ . This first estimate depended, however, on values of the seismic velocity gradients in the core, some of which were very uncertain, especially near the inner core boundary, which has proved to be far from a simple boundary. My first estimate of  $\rho_0$  rested on a  $P$  velocity distribution of Jeffreys which gave a transition region, 150 km thick, between outer and inner core, characterized by a high negative gradient for  $\alpha$ .

The estimate of  $\rho_0$  has had to be substantially modified during the past few years. In our work on hydrogen bomb explosions, Burke-Gaffney and I came across unmistakable evidence of early  $P$  wave arrivals at angular distances between 130° and 140° from the explosion source. Certain arrivals were up to 13 seconds earlier than in the J.-B. tables. Around the same time, Gutenberg gave evidence of similar early readings from natural earthquakes.

Dr B. A. Bolt, then a member of my Sydney department, showed in 1961 that all existing seismic observations could be accounted for by including an additional branch in the  $P$  travel-time curve for waves in the core. The new branch required the core to contain an additional layer, making four in all—outer core, two tran-

sitional layers, and then the inner core proper. The last word has not yet been said, but seismologists are agreed that Bolt's new velocity distribution is much superior to the old—so much so that he became speedily translated from Sydney to a major chair in the United States.

In relation to my density problem, an important feature of Bolt's work was that it removed the evidence on negative  $P$  velocity gradients in the core. This result led me in 1962 to reduce my estimate of  $\rho_0$  from 18 to 15 g/cm<sup>3</sup>.

In the meantime, two further developments have taken place which have led me to carry my density revision further in the lower core. The first was the assemblage, by Francis Birch of Harvard, of a body of evidence which points to a value not exceeding 13 g/cm<sup>3</sup> for the Earth's central density. The evidence includes shock-wave experiments involving short-lived pressures reaching the order of the pressures in the Earth's core. There are some controversial questions on the interpretation of the experiments, but Birch's estimate of 13 g/cm<sup>3</sup> for  $\rho_0$  has to be taken seriously.

The second development was some theoretical work of my own, seeking to extend the Williamson-Adams method to provide a serviceable equation on density gradients in regions of the Earth's deep interior where one cannot assume chemical homogeneity. In 1964, I applied this theory, and came to the conclusion that Birch's figure of 13 g/cm<sup>3</sup> for  $\rho_0$  could be met in only one way.

In making my previous estimates of  $\rho_0$ , I had assumed that the  $S$  velocity  $\beta$  in the inner core would have similar gradients to the  $P$  velocity. But there is no available test of this assumption. Various difficulties have so far made it impossible to detect and measure  $S$  waves in the inner core.

I found that I could accommodate a central density of 13 g/cm<sup>3</sup> only by departing from my previous assumption and having a negative gradient for  $\beta$  in the lower core. And a negative  $S$  velocity gradient demands a negative rigidity gradient if the density is not to go well beyond 13 g/cm<sup>3</sup> at the centre.

Thus if Birch's work proves to be substantiated, I think I have shown that, after an initial change from the molten to the solid state somewhere well down in the core, there is a trend back towards fluidity as the centre is approached. Moreover, additional evidence is provided on the solidity of the inner core. For there cannot be a negative rigidity gradient unless there is rigidity, i.e. solidity. More specifically, the calculations show that an entirely fluid core would, on the current seismic data, require the central density to be at least 14½ g/cm<sup>3</sup>. Part of my time during leave in 1964 was spent working out a number of models for the Earth's lower core exhibiting the range of possibilities.

### Planetary Interiors

I shall now touch, perforce briefly, on one or two aspects of my interest in planetary interiors. This interest goes back to 1937 when I used my first density-pressure results for the Earth to see what light might be thrown on the comparative compositions of the Earth and the terrestrial planets. In that year, Jeffreys and I independently showed that if the mantles of the Earth, Venus and Mars are similarly composed, and also the cores, but the mantles chemically distinct from the cores, then the mantle-core mass ratios would have to be very different for the three planets. It therefore seemed that the overall compositions of the planets must be significantly different.

This conclusion was favoured until, over the period 1948-50, W. H. Ramsey of England and I tried a new idea. We independently showed that if the change from mantle to core in the Earth were principally due to pressure rather than

change of composition—if the change were essentially a phase transformation—then one could, to good approximation, fit the available astronomical data and the pressure-density relation for the Earth, and still have the same overall composition for all three planets.

There are, however, some obstacles to this idea. There are complications with the planet Mercury, and geochemists do not favour the phase transformation idea because of the large jump in density at the Earth's mantle-core boundary. Nevertheless, it has not yet proved possible to obtain a decisive test. For a period of years, the theory received little attention, but it has lately come into the news again, notably at the hands of R. A. Lyttleton who has used it in a new theory of the Earth's mountain building.

An interesting aspect of the theory is that it entails a much smaller fluid outer core in Venus than in the Earth, and no fluid zone in Mars. If one accepts the current view that the main seat of the Earth's magnetism is in the fluid outer core, it would then be expected that Venus has a much weaker field than the Earth, and Mars an extremely small field, if any. So far as artificial satellite observations have gone, these results seem to be substantiated.

What is really wanted now is seismograph recordings on the planets. If we could, for example, thereby locate and estimate the thickness of a Venusian fluid outer core, we should be well on the way to checking important inferences on the interior of the Earth. Thus it is that the interiors of planets have become a recognized part of solid-Earth geophysics.

### Origin of the Moon

Another part of my extra-terrestrial work relates to the origin of the Moon. With the help of a student A. N. Datta, I showed that in certain circumstances a mass equal to that of the Moon could have been expelled from a primitive Earth-Moon body with explosive violence. This was a consequence of calculations on the gravitational energy of a planet containing a small core in the form of a phase transformation of the material outside.

It would be going too far to claim that these calculations provide more than one of a number of possibilities on the origin of the Moon. At the time they were made, there were heavy arguments on other grounds against the idea that the Moon and Earth were once a single body. But the calculations remain formally valid, and latterly there has been some renewed interest in the idea of a primitive Earth-Moon body.

### The Role of Mathematical Models

I should like, finally, to say that I have found research in geophysics to provide a great education in the philosophy of science. Physicists and some other scientists may sometimes think that they obtain factual results by direct observation in the laboratory. Where the deep interior of the Earth is concerned, there cannot be even the pretence of direct observation. This has led to two rather common attitudes, both unscientific. One is a tendency to build geophysical theories on flimsy evidence and, with fashion lending support, to attach quite unwarranted weight to highly doubtful inferences. The other attitude is a tendency on the part of some writers to dismiss results on the Earth's interior as 'inductive'—as if there existed any branch of natural sciences in which the inferences are not all inductive.

The method I have tried to bring to bear is inference through mathematical models. As I see it, all discussion in natural science, whether in geophysics or any other science, is in terms of mathematical models, using the word 'mathematical' in

a very broad sense. I would regard the central aim in science to be the erecting of mathematical models which will describe fields of observational data as accurately and tersely as possible. Formal mathematics does not necessarily have to be used, particularly in the early stages. There are parts of geology, for example, where it would be foolish to apply sophisticated mathematics. Also, mathematics alone must never be allowed to dictate. But the spirit of applied mathematics should, in my view, be present in all scientific discussions.

No mathematical model, whether given the august name of 'law of nature' or not, should ever be confused with reality. The task, as I see it, is to sort the models out into some order of reliability in relation to the evidence available at the time.

In geophysics, it is perhaps fair to say that, due to paucity of crucial evidence, there is more than the usual number of flimsily established models. On the other hand, the properties of some other geophysical models appear to be as reliably established as many ordinary laboratory results. Thus inferences in geophysics appear to me to be of the same general character as in all science. I hope that in this address I have succeeded in giving some indication of the weights I think should be attached to the various parts of my work.

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# *MALUROSTROPHIA*, A NEW GENUS OF STROPHEODONTID BRACHIOPOD FROM THE DEVONIAN OF AUSTRALIA

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## Abstract

*Malurostrophia* gen. nov., an external homeomorph of *Leptodontella*, is considered to be derived from *Nadiastrophia* from which it differs principally in having ventrally deflected lateral margins and a dorsally deflected tongue, or from *Douvillinea* which has dorsally deflected lateral margins, but lacks a tongue. It occurs in beds of Eifelian or late Emsian age in eastern Australia in what appears to be a restricted zone. Two new species are described: *M. flabellicauda*, the type species, and *M. basilica*. Its ontogeny and the biological significance of certain of its structures are discussed. Interpretations of its feeding mechanism, the form of its lophophore and the disposition of its visceral cavity differ from previous reconstructions of strophomenid brachiopods.

## Introduction

Well preserved silicified stropheodontids externally resembling the stratigraphically restricted genus *Leptodontella* Khalifin occur in abundance at Taemas, New South Wales. Recent work on a revision of the Pholidostrophiinae (Harper, Johnson & Boucot 1966) and unpublished work on forms resembling *Leptodontella* has indicated the relevance of describing this material together with material of the genus from elsewhere in Australia.

We are indebted to Prof. A. J. Boucot for encouraging us to write this paper; to him and Dr J. G. Johnson of the California Institute of Technology, and to Dr Charles Harper of the University of Oklahoma for generously sending us copies of their manuscript on the Pholidostrophiinae in advance of publication; to Mr B. Chatterton for making available certain specimens from Taemas; to Dr G. Arthur Cooper for the loan of the dorsal interior of *Leptodontella caudata* described by Williams (1953) and the specimen reproduced on Pl. 50, fig. 13; to Prof. H. B. Whittington for the specimen on Pl. 50, fig. 11; to Mr Leo Seeuwen and Mr Philip Boek for the photographs of plates 47-49; to Miss J. Shepherd for the draughting of text-figures; to Dr M. J. S. Rudwick and Dr J. G. Johnson for critical comment; and to Dr D. E. Thomas, Director of Geological Survey, Mines Department, Melbourne, for permission for one of us (J.A.T.) to publish. The views expressed are entirely our own responsibility.

## Systematic Description

Family STROPHEODONTIDAE Caster 1939

Genus *Malurostrophia* gen. nov.

DERIVATION OF NAME: Allusion to the Maluridae, the Australian fairy wrens, notable for their elegant erect tails.

TYPE SPECIES: *Malurostrophia flabellicauda* sp. nov.

**DIAGNOSIS:** Unequally parvicostellate stropheodontids having a thin body cavity; valve margins sharply geniculate and ventrally directed except for a prominent dorsally directed tongue in the anterior margin, and reflexed lateral margins in front of the ears in some large specimens. Pedicle valve with an anteriorly bilobed rhomboidal diductor field and strong muscle bounding ridges; in adults marginal ridge pronounced laterally, rarely continued across the inner surface of the tongue. Brachial interior with roundly triangular muscle scars bounded laterally by high ridges, and divided medially by a shallow furrow; medial pair of adductor scars situated well back and lying astride the transmuscle ridges (= 'brace plates' of most recent literature. It is argued below in the section on Functional Morphology that these structures did not support the lophophore: the term is therefore misleading.) The transmuscle ridges are continued forwards and increase abruptly in height in front of the muscle scars; low brevisseptum present in front of muscle scars; in large specimens shell thickening forms an antero-medial prominence over and a little in front of the distinct pit on the exterior of the brachial valve; a corresponding pit occurs on the interior of the pedicle valve; hinge line denticulate for approximately half its length; cardinal process lobes disjunct; socket plates present.

**GENERIC RELATIONSHIPS:** The systematic division of the Stropheodontidae is at present quite unstable; the extent of the instability can be gauged from a comparison of the genera included in the Pholidostrophiinae by Williams (in Moore 1965) and Harper *et al* (1967). For this reason we have not discussed the assignment of *Malurostrophia* to a subfamily, but have been content to indicate relationships with existing genera.

Though the external shape, thin body cavity, and ornament of *Malurostrophia* are very similar to those of *Leptodontella* Khalifin, there are reasons for believing that the relationship between these genera is more remote than such similarities might indicate. *Leptodontella* has very flabellate diductor scars in the pedicle valve and correspondingly widely spaced 'brachial ridges' in the brachial valve; it has no true socket plates and no transmuscle septa; it has a median ridge running up to the base of the cardinal process, the lobes of which are not as sharply disjunct as those of *Malurostrophia*; its hinge line is completely denticulate; and it does not develop a sharp prominence on the median anterior of the brachial valve. We consider the external similarities of these two genera to be adaptations to feeding in a similar orientation with respect to the substrate, a phenomenon also known in the leptaenids (see section on Functional Morphology below).

Comparison may also be made with *Douvillina* Oehlert, as interpreted by Williams (1953, and in Moore 1965); their external shapes are entirely different. *Douvillina*, in common with many stropheodontids, has a strongly and evenly convex pedicle valve, a closely fitting concave brachial valve, and consequently a thin body cavity. Note that these differences involve the whole shell and not only the marginal deflexions. Internal similarities include strong lateral bounding ridges in the muscle field of the pedicle valve, well developed transmuscle septa, a vestigial chilidium, disjunct cardinal process lobes and strong lateral muscle bounding ridges not everted posteriorly; the socket plates and the brevisseptum are obsolescent, and the cardinal process is differently oriented. We conclude that the differences are more significant than the similarities and that there is no close relationship between the genera.

The muscle scars in the pedicle valve of *Malurostrophia* are reminiscent of those of *Shaleria* Caster in that they are long and narrow, bounded laterally by strong

ridges that are posteriorly everted, and deeply cleft in front by muscle bounding ridges. Further, the shallow body cavity, ornament, form of the pseudodeltidium and ventral process, and the denticulation are similar in the two genera. The shape of the muscle bounding ridges and the transmuscle septa, and the lack of a brevisseptum and socket plates, do not confirm any suggestion of relationship. *Telaeroshaleria*, now removed from proximity to *Shaleria* (Harper *et al* 1966) has a somewhat similar interior in the pedicle valve, strong transmuscle septa and a brevisseptum not unlike those of *Malurostrophia*, but it is deep bodied, has a powerful marginal ridge in the brachial valve, and cardinal process lobes of a most distinctive pattern.

*Douvillina* Sprickersbach (1925) has been used to embrace resupinate Devonian douvillinids. Its late Emsian type species, *Douvillina filifer* Schmidt (1912) has cardinalia and musculature in the brachial valve similar to the present genus, but has an essentially subcircular muscle field in the pedicle valve composed of two broadly ovate to rounded trigonal adductor scars. This, the resupinate character, and the absence of a dorsally deflected tongue are sufficient to separate them; but the similarities are such that *Malurostrophia* could conceivably have been derived from *Douvillina*, a genus not yet known from Asia or Australia.

It is with the genus *Nadiastrophia* Talent, from the Lower Devonian of Victoria and the Middle Devonian of China, that we consider *Malurostrophia* has the greatest propinquity. They both have unequally parvicostellate ornament, a shallow body cavity, an extended hinge, elongate anteriorly cleft muscle scars with everted lateral bounding ridges in the pedicle valve, strong transmuscle septa and lateral muscle bounding ridges in the brachial valve, peg-like cardinal process lobes which are similarly oriented, blade-like socket plates set in similar positions, and a distinct brevisseptum. The lateral margins of the valves, however, are directed in opposite senses, a feature which gives the two genera a misleading impression of disparity. They also differ in the relative proportions of the adductor scars in the brachial valve, the more extended denticulation of the hinge and in the apparent absence of vascula dentalia in *Nadiastrophia*. These differences are considered to be minor. In view of their stratigraphic positions, it is concluded that *Malurostrophia* was derived from *Nadiastrophia*. It is noted that although Talent (1963, p. 62-3) considered *Nadiastrophia* to be allied to the shaleriids, Harper *et al* (1967) have transferred it to the Pholidostrophiinae, an assignment we find difficult to accept.

#### *Malurostrophia flabellicauda* sp. nov.

(Pl. 47, fig. 1-16; Pl. 48, fig. 1-20; Pl. 49, fig. 1-8; Pl. 50, fig. 8-10; Fig. 1-10)

**TYPES:** Holotype 14620; paratype 14614-19, 14621-67, 14982-93, all Australian National University.

**DESCRIPTION:** **Exterior of pedicle valve.** Earliest growth stages of pedicle valve having a relatively broad median furrow, but shell overall convex; slight medial ventral deflexion beginning at length of 4-5 mm and increasing rapidly in height, width of deflexion showing considerable variation; ventral deflexion of entire shell margin beginning at this stage, followed later by reversal of deflexion of median sector and its positive allometric growth in a dorsal direction. Hinge of earliest growth stages not observed; at shell width of 3-4 mm hinge extremities subrectangular, then becoming slightly alate, alation increasing with further growth. Ornament unequally parvicostellate throughout; median furrow and median rib present at earliest stages (for arrangement of primaries see Pl. 47, fig. 2, 4, 7); secondaries tending to be introduced at  $\frac{1}{3}$  to  $\frac{1}{2}$  length of the valve, attaining same

size as primaries; tertiaries of more or less uniform size, all apparently intercalated; uniform lirae cover the shell surface between the costae and costellae, increase by intercalation, and number 4-5 per half mm at the geniculations; ornament on tongue stronger than elsewhere, with quite large costellae inserted and reaching maximum size within about 1 mm after insertion. Cardinal area gently concave in adults; outline of delthyrium not clearly distinguishable; pseudodeltidium bearing a high median fold. Pedicle foramen occupies the tip of the umbo and is 0.07-0.1 mm in diameter at the time of pedicle atrophy, i.e. a little before the period of initial shell geniculation; pedicle tube passes through the shell at a very low angle to the external shell surface (Pl. 48, fig. 17-18); no sign of pedicle sheath, though its apparent absence could be the result of weathering.

**Exterior of brachial valve.** A small protegular node is present and is extended forward for c. 1 mm as a vague ridge from which the primary costae are derived (Pl. 47, fig. 1, 3, 5). Cardinal area linear; notothyrium triangular, higher than wide; chilidium indistinct, variable in shape but often with a node at the apex, a concave ventral edge (which is sometimes slightly raised), and a slightly depressed central region (Pl. 48, fig. 4; Pl. 49, fig. 3).

**Interior of pedicle valve.** Ventral process present early as a very faint mound, beginning to develop at the same growth stage as the tongue, merging anteriorly into a pair of ridges bounding the postero-lateral edges of the adductors; process pits deep. Muscle fields of juveniles relatively wide; muscle scars at shell width of 5-6 mm bounded postero-laterally by a slight thickening; strong postero-lateral muscle bounding ridges rising above shell surface are present when the marginal deflexion develops (Pl. 47, fig. 12), but the antero-lateral and anterior edges of the muscle scars, though distinguishable, are not defined by ridges. In adults, the outer edges of muscle scars are invariably defined by ridges or plates of a very distinctive shape, the postero-lateral portions being massive and having their dorsal edges bent sharply outwards forming a platform-like structure (Pl. 48, fig. 15; Pl. 49, fig. 4-7); the muscle bounding ridges drop sharply in height in front of this structure, gradually diminishing to the anterior edge of the scars; widest part of scars at about their mid-length and just anterior to the 'everted' part of the bounding ridges; each diductor scar tapered anteriorly, rounded in younger individuals, produced to a blunt point in the largest specimens; inner edges of diductor scars bounded by weak ridges; adductor scars ovate to semi-cordate, slightly platformed. In two juvenile pedicle valves 3 mm and 3.5 mm long and 5.5 and 5.2 mm wide respectively, the medial muscle-bounding ridges are high and pustulose, with very feeble expression of the lateral ridges; these are quite strongly expressed in our remaining material 11 mm wide or larger. A thickened ridge extends around the valve inside the deflexion, merging into a triangular postero-lateral platforming of the inner edges of the ears. It usually dies out against the tongue, but in some specimens continues onto the inner surface of the tongue, and very rarely completely traverses it; the marginal ridge is initiated soon after deflexion of the valve edge (Pl. 47, fig. 12) and continues to develop throughout life, its dimensions depending on the age of the individual (Pl. 47, fig. 13-15; Pl. 49, fig. 4-8). A distinct groove or channel (vasculum dentalium) runs from the body cavity to each of the cardinal extremities, lying in front of and at a low angle to the hinge; it is present in young specimens, becoming particularly prominent in adults bearing wide ears; it is sometimes vaguely divided by an indistinct longitudinal ridge (Pl. 49, fig. 6) and is markedly shallower where it crosses the marginal ridge (c.g. Pl. 47, fig. 13-15; Pl. 49, fig. 6-7). Denticles are apparently absent in specimens 5 or 6 mm long; 7 to 11 denticles are

present on each side of the umbo and occupy a little more than half the length of the hinge at the stage where marginal deflexion begins; in adults there are up to 22 denticles on either side of the umbo; the denticles are borne on a ridge, and increase gradually in size from the extremities towards the muscle-bounding ridges, then rapidly diminish towards the midline (Pl. 47, fig. 14; Pl. 49, fig. 5-7).

Articulation of valves as follows: the socket plates of the brachial valve fit into a socket in the pedicle valve lying between the inner edges of the tooth plate and the outwardly deflected edges of the muscle-bounding ridges; the broad ridges running antero-laterally from the cardinal process of the brachial valve then lie flat against the outwardly deflected edges of the muscle-bounding ridges. The denticulation of the brachial valve is actually a series of sockets lying in a groove, that of the pedicle valve being a series of denticles arranged on a ridge, the groove and ridge in both cases extending laterally beyond the denticulation and forming a weakly ginglymoid type of dentition.

Mantle canal system not clearly impressed on the shell in available specimens except for the vasculum dentalium which passes into a strong groove extending towards the ears and lying almost parallel to the hinge. The inner surface does however bear a radiating series of grooves corresponding to the ribs of the exterior of the shell; these become progressively lost toward the muscle scars but are retained or become intensified on the deflected margins and on the inner surface of the tongue where they are particularly densely packed (Pl. 47, fig. 16). The internal expression of surface ornament on the body of the shell is highly variable, some geniculate specimens showing the eostae, the eostellae and the lirae, the latter being outlined by rows of pustules. In the majority of specimens there is no differentiation on the inner surface between coarser and finer ornament on the body of the shell; in larger specimens the pustules become more random in distribution with a general tendency to become finer towards the geniculate portions. The pustules are often noticeably hollow.

**Interior of brachial valve.** Hinge line consisting of a dental groove extending to the cardinal extremities, denticulate for approximately half its length. Cardinal process lobes disjunct, circular to ovate in cross-section, each becoming distinctly bifid in specimens 12 mm or more in width, diverging between  $40^{\circ}$  and  $60^{\circ}$  from each other, and directed posteriorly at  $65^{\circ}$  to  $70^{\circ}$  to the floor of the valve. Socket plates blade-like, aligned at  $c. 20^{\circ}$  to the hinge line. Lateral muscle bounding ridges typically arcuate and pustulose, joined to the posterior thickened shelf paralleling the hinge line, but not joined or only feebly joined to the transmuscle septa; these ridges lie with their ventral edges immediately opposite the everted edges of the muscle bounding ridges of the pedicle valve. A low, vaguely defined areuate and pustulose ridge (Pl. 48, fig. 7) runs forward from the muscle bounding ridges in adults (= the lateral brachial ridge of Harper *et al.*). Adductor scars roundly triangular in outline and divided by a shallow median furrow; lateral scars sausage-shaped in outline, and spread well up to the lateral ridges; median scars tear-shaped with their posterior edges bluntly pointed and situated a short distance in front of the posterior edge of the lateral scars, their inner edges close to the mid-line of the shell. A transmuscle septum bisects each median adductor scar and increases abruptly in height on emerging from its anterior edge; these septa are most obvious beneath the scars in young specimens, but become progressively more obliterated with age by the deposition of muscle callus (Pl. 48, fig. 14, 5, 2, 3 show specimens of increasing age). In young specimens transmuscle septa terminate abruptly anteriorly, but in adults low anterior extensions converge to outline a canoe-shaped

structure divided by a low median brevisseptum and rising to a low eminence at a point 0.6-0.7 of the distance from the posterior shell margin to the geniculation. Surface anterior to this structure has a pronounced rounded ridge rising up the geniculate area to a pointed pyramidal prominence corresponding to a distinct but vaguely defined pit on the exterior, the point where an abrupt reverse in sense gives rise to the tongue.

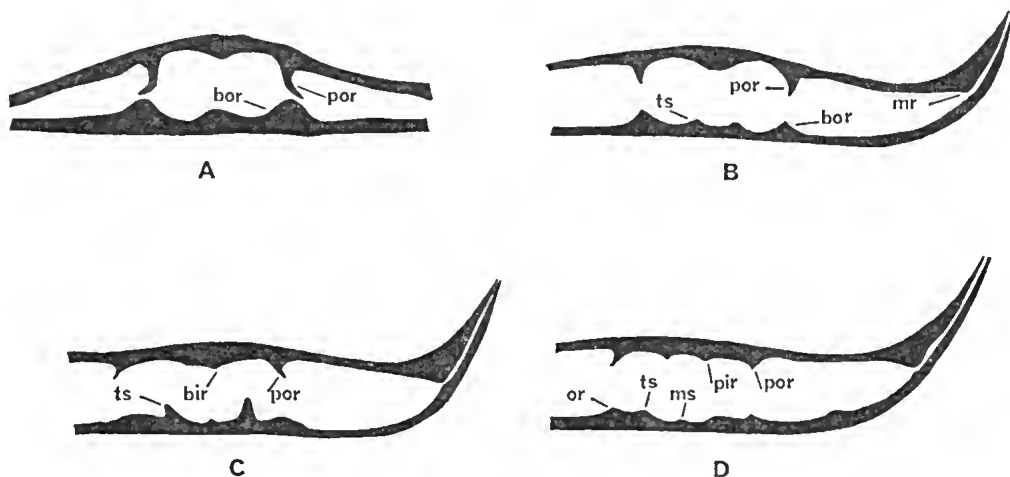


FIG. 1—Serial sections across specimen ANU 14992. Intervals between sections are as follows: 0.4, 0.8, 0.4 mm. bor = outer muscle ridge in brachial valve; c = excrescence; mr = marginal ridge; ms = brevisseptum, or = 'lateral brachial ridge'; pir and por = inner and outer muscle bounding ridges in pedicle valve; ts = trans-muscle septum.

Mantle canal system usually not impressed, but details can be reconstructed from three well preserved individuals (Pl. 48, fig. 6-10; Fig. 2). A clear vasculum cardinalium passes into a prominent groove on the ears, directed at  $4^{\circ}$ - $10^{\circ}$  to the hinge. This lies opposite the comparable groove on the pedicle valve. There is no sign of saecate vascula genitalia, and this structure can best be described as pinnate. The vaseula myaria are many branched and serve the water intake sector of the shell edge. The ramifying vascula media serve the entire deflected median sector.

DISCUSSION: A few points in the above description need further comment.

The outlines of the species are very variable as can be seen from the plates, the plots of dimensions (Fig. 3-7; Table 1), and the figures. It should be noted that because of the geniculation the dimension 'length' is not a reflexion of the amount of growth in a plane at right angles to the hinge. The curvatures shown by the plot in Fig. 3 are due partly to the early allometric growth of the hinge, and partly to this artifact. Estimates of total width have frequently to be made from specimens with broken or partly silicified ears, but this is unlikely to involve any considerable error.

Measurement of the distance between the hinge-line and the point of the anterior node of forty-five specimens gave a mean of 4.91 mm, a standard deviation of 0.69 mm, and a total range of 3.7-7.0 mm, though only three individuals have values  $>5.5$  mm and one  $<4.0$  mm. This dimension is independent of age and is a useful one in distinguishing between the two species described herein.

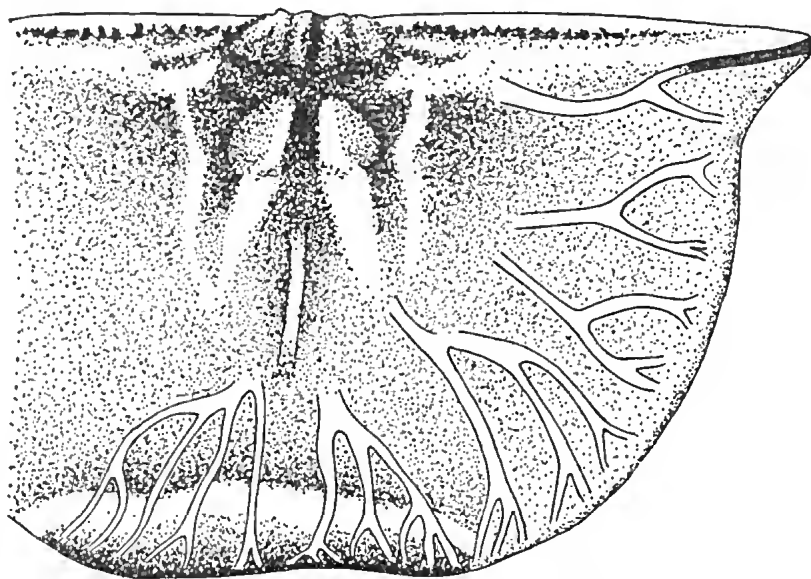


FIG. 2—Reconstruction of the mantle canal pattern in the brachial valve of *Malurostrophia flabellicauda*, based mainly on ANU 14984 and ANU 14619. (Compare with Pl. 48, fig. 6, 7, 9, 10.)

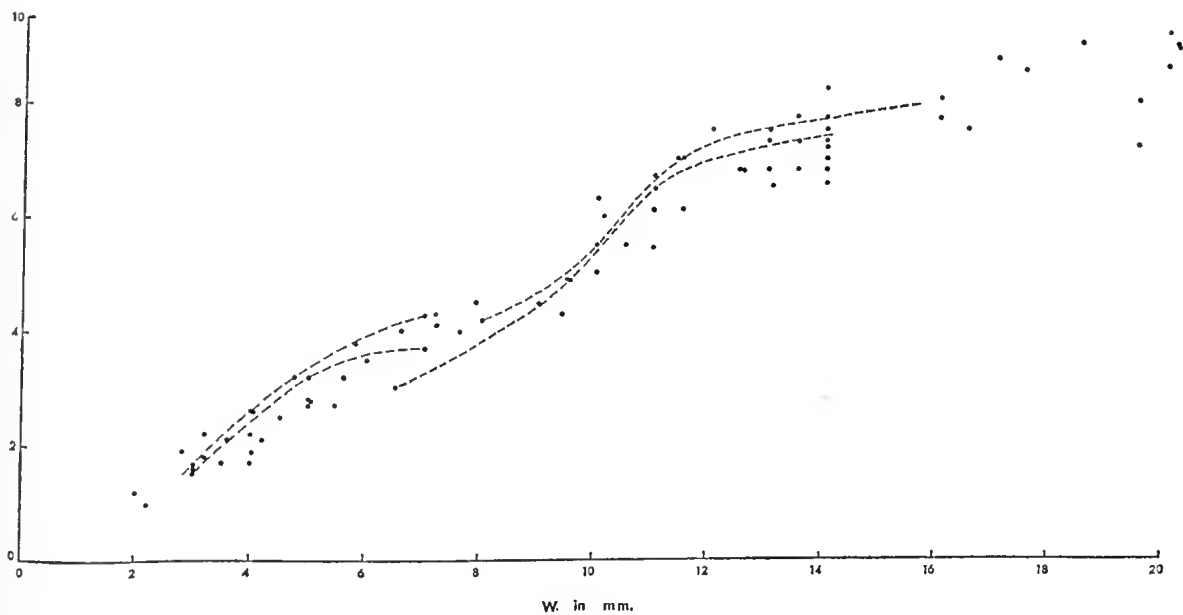


FIG. 3—Plot of Total Shell Length against Total Shell Width. The dotted lines indicate growth patterns of four specimens.

Width of the Fold also is very variable. It varies with age. For this reason it is shown in Fig. 4 and 5 plotted against the Length of the Muscle Sear in the Pedicle Valve, a dimension which apparently shows linear increase with age, and against Total Shell Width. The growth lines suggest also that the latter increases linearly with age beyond the stage where the fold develops. Both show a wide scatter; the value of the correlation coefficients are  $r = +0.45$  ( $n = 31$ ) and  $r = +0.61$  ( $n = 31$ ) respectively.

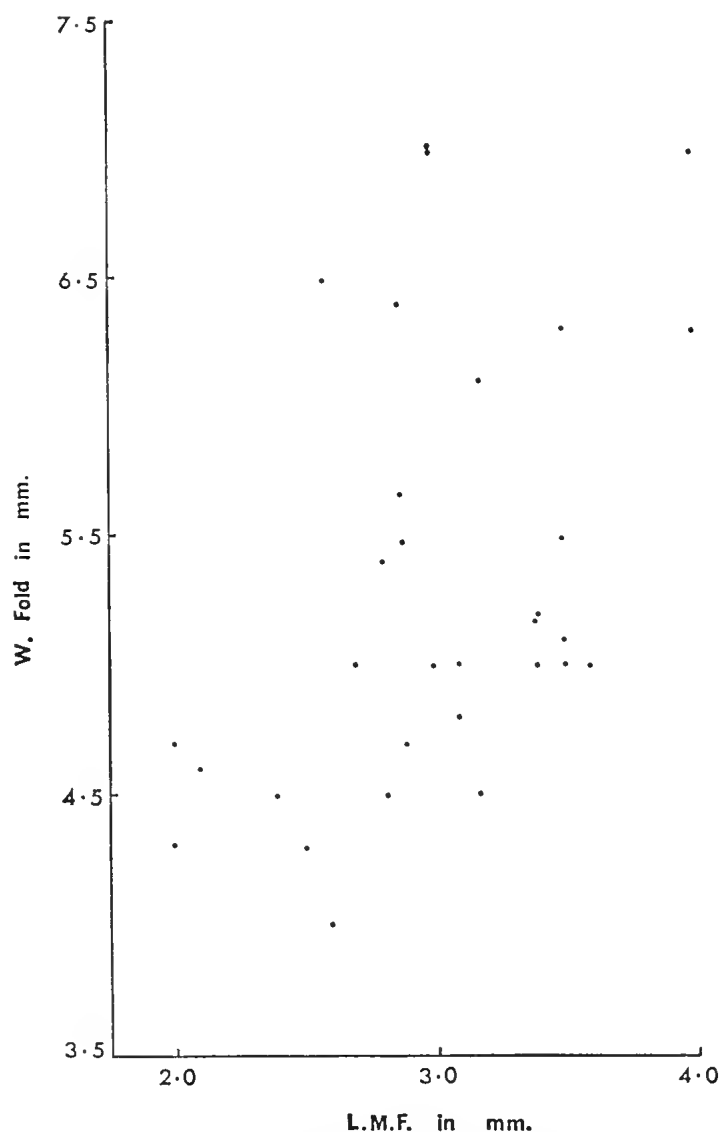


FIG. 4—Plot of Length of Muscle Field in Pedicle Valve against Width of Fold of *Malurostrophia flabellicauda*.



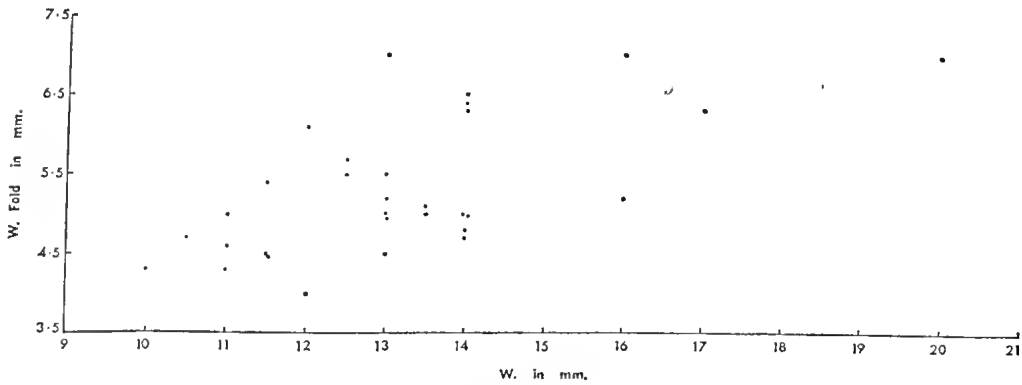


FIG. 5—Plot of Total Shell Width against Width of Fold of *Malurostrophia flabellicauda*.

The plot of Length of Musele Sear against Width of Musele Sear (in the pedicle valve) exhibits a considerable range of variation. The relatively narrower specimens usually fail to show a bulge in the outline of the sears near their mid-length. The value of  $r$  is  $+0.79$  ( $n = 41$ ).

Two further features, variations in which profoundly modify the overall appearance of the shell, are the amount and angularity of the ventral median deflexion that produces the median node (cf. Pl. 47, fig. 6 and 7; Pl. 48, fig. 20), and the time of onset of the reflexion of the margins in front of the ears (cf. Pl. 47, fig. 14-15; Pl. 48, fig. 15, 16, 20 with Pl. 49, fig. 6 and 7).

Finally, the adductor sears in the brachial valve are poorly differentiated into anterior and posterior pairs until the late adult stage. The anterior sears lie astride the posterior ends of the transmuscle septa which are only partially resorbed. At the late adult stage, however, resorption is greatly increased, the septa show an abrupt increase in height at the edge of the muscle field, and the anterior adductor muscles build distinctly platformed sears.

**DISTRIBUTION:** Silicified specimens occur in great abundance in limestones of the *Receptaculites* Limestone at Bloomfield Station, Taemas district, near Yass, and in the Crinoidal Limestone, Hume Park, near Yass, N.S.W. (for stratigraphy see Browne 1959). It occurs in relative abundance, but less well preserved, in the *Calceola* band of the lower Murrindal Limestone on the crest of the ridge running east from Rocky Camp, Buchan, Victoria (for stratigraphy see Teichert & Talent 1958). A poorly preserved specimen of what may be the same species occurs in collections made by the Bureau of Mineral Resources, Geology and Geophysics, at locality B76, Ukalunda Beds, Ukalunda, Queensland. On present information the best age estimate for all these localities is in the range late Emsian-Eifelian.

#### *Malurostrophia basilica* sp. nov.

(Pl. 50, fig. 1-7)

**DESCRIPTION:** **Exterior of pedicle valve.** Hinge extremities broken on available specimens, but obviously alate in the unbroken state. Pedicle valve more or less planar with a ventral deflexion of the entire shell margin beginning at about 9 mm, followed by reversal of deflexion of the median area at about 10 mm from the umbo to form a dorsally directed rounded tongue. Tongue about 5 to 6 mm wide. Orna-

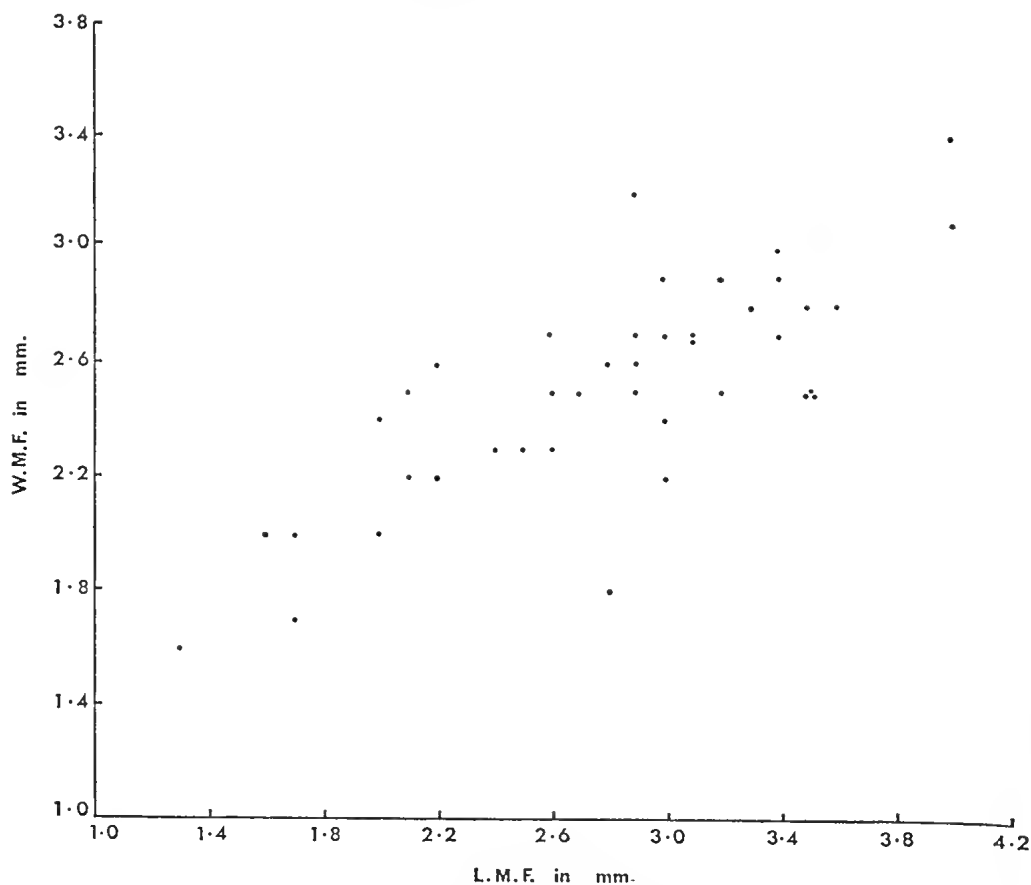


FIG. 6—Plot of Length of Muscle Field against Width of Muscle Field (in the pedicle valve) of *Malurostrophia flabellicauda*.

ment parvicostellate throughout, but with primaries more closely spaced (5 or more in 3 mm) and more numerous at any given growth stage than in *M. flabellicauda*, and with stronger secondaries giving, on first glance, the impression that the ornament is costellate rather than parvicostellate; ornament on tongue costellate. Cardinal area gently concave.

**Interior of pedicle valve** (Pl. 50, fig. 7). Ventral process merging anteriorly into a strong pair of ridges bounding the adductor field. Diductors bounded by strong muscle-bounding ridges, strongly expressed even around the anterior margins of the diductor scars; scars directed away from each other initially, but tending to be parallel in the adult stage, extending to about midlength; widest part of the scars situated anterior to their midlength; each scar tapered anteriorly. Adductor scars elongate-ovate, completely enclosed by diductors and separated from them by a pronounced ridge. A thickened ridge extends around the valve inside the marginal deflexion, but not known in detail in the vicinity of the tongue. Denticulation and mantle canal system not known.

**Interior of brachial valve** (Pl. 50, fig. 6). Cardinal process lobes disjunct.

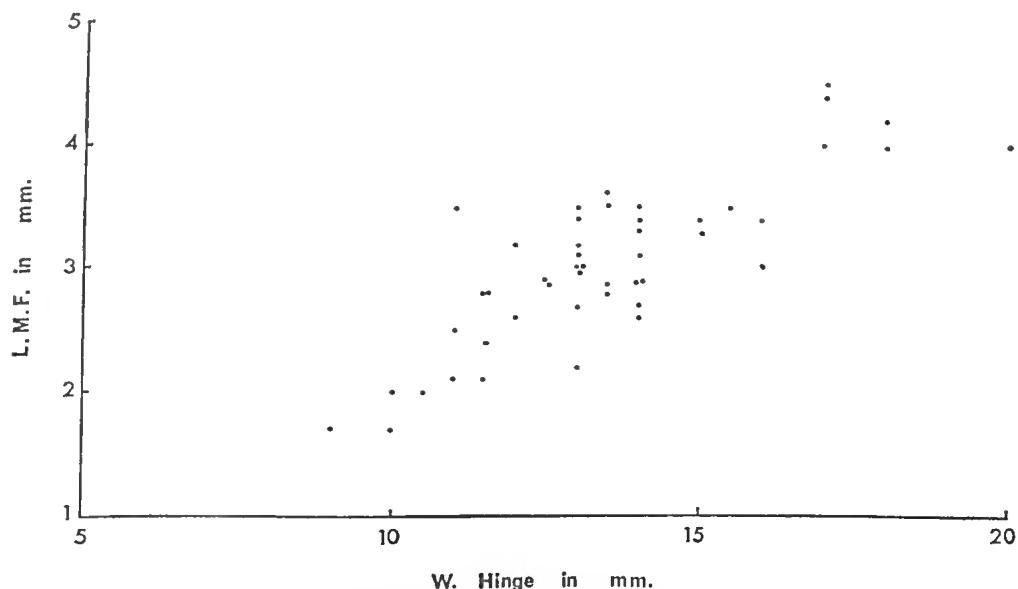


FIG. 7—Plot of Width of Hinge against Length of Muscle Field in the Pedicle Valve of *Malurostrophia flabellicauda*.

Lateral muscle-bounding ridge arcuate, concave on their outer margins, joined to the posterior thickened shelf paralleling the hinge line, but not joined to the median muscle-bounding ridges. Adductor sears roundly triangular. Transmuscle septa broad and slightly sinuous, median septum broad and forming a pronounced transversely oriented node. Inner surface anterior to the muscle field having a pronounced rounded ridge parallel to the margin and rising to a median node. Inner surface papillose, not showing impressions of the mantle canal system.

**DIMENSIONS (mm):** Two specimens from locality 16, Bindi, Victoria, have the following dimensions;

	Length	Width	Maximum height
Holotype (GSV 58553)	12.5	18.6+	8.4
Paratype (GSV 58554)	11.7+	16.0+	5.2

**DISCUSSION:** *M. basilica* differs from the type species of *Malurostrophia*, *M. flabellicauda*, in having less markedly parvicostellate ornament and a less fan-like arrangement of the costellae on the tongue. The lateral muscle bounding ridges of the brachial valve are more sinuous than in *M. flabellicauda*, and the transverse node delimiting the anterior adductor sears is more strongly expressed. Of obvious importance is the much greater size of *M. basilica*. It cannot be construed as having been based on gerontic individuals of *M. flabellicauda* for geniculation occurs in the latter at c. 5 mm from the hinge line compared with at about 9 mm in *M. basilica*—i.e. at the same relative maturity *M. basilica* is an altogether more robust species.

**LOCALITY:** Known only from the Taravale Formation at locality 16, a washout on the south side of a gully draining to Junction Ck, 1,450 yards south-east of the Sugarloaf, Bindi, Victoria. This locality is about 1,700 ft above the top of the Buchan Caves Limestone and represents an horizon stratigraphically higher than

that which yielded *M. flabellicauda* and *Calceola* at Buchan, perhaps 1,000 ft higher. Present evidence (Talent 1965) indicates that these beds are not older than Upper Emsian and are most probably Eifelian in age.

### Functional Morphology

#### EVIDENCE OF SHELL ORIENTATION, SHELL ATTACHMENT, AND FEEDING CURRENTS

With regard to gross shape there are four growth stages to be functionally interpreted.

**Stage 1.** At the initial stage the shell was attached by a pedicle. As a result of incomplete silicification of the shell margins it is not possible to state with certainty the shell size limits within which the pedicle atrophied, but it is approximately at the period of initial geniculation. No pedicle sheaths have been observed but in several individuals the angle at which the pedicle passed through the shell can be determined. In shells which have not quite become geniculate the foramen occupies the tip of the umbo and the pedicle tube passes anteriorly through the test at a very low angle to the external shell surface (Pl. 48, fig. 17-18). This angle is much lower than that observed in certain species of *Leptaena* (Arber 1939, 1940). The natural position of a shell attached by a pedicle oriented in this direction would be with its brachial valve downwards. Assuming that a lophophore existed in this group and that it produced a pair of lateral incurrents and a median excurrent, such a position would be feasible provided the organisms were held free of the soft substrate by attachment to some hard object.

**Stage 2.** When the pedicle atrophied, the shells would subside preferentially on to their brachial valves because of their orientation while attached. Specimens that came to rest on their pedicle valves would either die because the valve edges would be in the substrate, or perhaps invert themselves by clapping the valves together. Since death would ensue for many, one would expect a mortality peak at this shell size. This is yet to be checked. Those oriented with the pedicle valve upwards would feed in the normal way, the entire shell edge being above the substrate. It is significant that ears began to appear on the hinge while the shell was still attached by the pedicle, and they continued to grow with positive allometry, thus providing some stability for the shell when it became free.

**Stage 3.** In young adults, though the lateral margins continue their ventrad growth, the median sector is reflexed dorsad and would thus tend to be immersed in sediment. Whilst this, together with the extended ears, would make for high stability, it would create problems with regard to the disposal of water in a median excurrent.

There is, however, evidence in both *Leptodontella* and *Malurostrophia* to suggest a modification of this current. The ventrad and subsequent dorsad deflexion of the median sector results in transverse lobation of this region, and in the formation of a pair of shallow channels directed laterally from the mid-line to the margins of the median deflexion (e.g. Pl. 47, fig. 16). In addition, *Malurostrophia* has these channels emphasized by the formation in the brachial valve of a sharp triangular median node with a distinct posterior ridge (Pl. 48, fig. 1, 11). Such an arrangement would split the median excurrent into two, allowing it to pass out on the flanks of the tongue above the substrate; it would also account for the break in the internal marginal ridge in the pedicle valve of most specimens where it commences to cross the tongue (Pl. 47, fig. 14; Pl. 49, fig. 4-8). The ridge is

continued across in some individuals, but even in these it weakens at the edge of the tongue.

At this growth stage the extended hinge region becomes tubular (Pl. 47, fig. 12-16; Pl. 48, fig. 15-16) and it has been suggested (Orton 1914; but cf. Rudwick 1960) that in some genera these tubes may have been feeding devices. Such a view cannot be supported. The orifices at the ends of the hinge would tend to be submerged, and in any case the internal marginal ridge constricts the tube where the two structures intersect. The tubes were more probably the sites of strong vascular trunks for carrying coelomic fluids to the ears, which were very active regions of shell deposition, that is, they were deeply impressed pallial markings. Some credence is lent to this view by the wealth and strength of the trunks supplying the other rapidly growing edge, the median deflexion (cf. their density on the inner surface of the median deflexion, Pl. 47, fig. 16; Pl. 49, fig. 6-8, with those on the marginal deflexions, Pl. 48, fig. 6 and Pl. 49, fig. 7).

**Stage 4.** In the oldest specimens the lateral margins in front of the ears are reflexed dorsally, leaving only the sectors on either side of the median deflexion directed ventrally. On the interior of the pedicle valve the axis of this reflexion is accompanied by slight thickening, and this sector is thus effectively sealed. Only the areas of water intake are then left standing above the substrate. The reflexed areas presumably provide additional stability.

If our discussion of the relationships of *Malurostrophia* and *Leptodontella* is correct this remarkable series of adaptations has been independently developed in the two genera. They have also been developed independently (Pl. 49, fig. 9-11) in the genus *Notoleptaena* Gill (= *Rugoleptaena* Havlíček). The functional significance of the external shapes of these genera has been discussed by Gill (1951, p. 196-199) and Kozłowski (1929, p. 92), both of whom believe that the shells rested on their pedicle valves, the lateral margins serving as an anchor and the tongue permitting the access of clear water. Gill apparently concluded that the incurrents were sited on the flanks of the tongue and that the excurrent was medial. Such an arrangement seems to us to be less likely than that suggested above because of

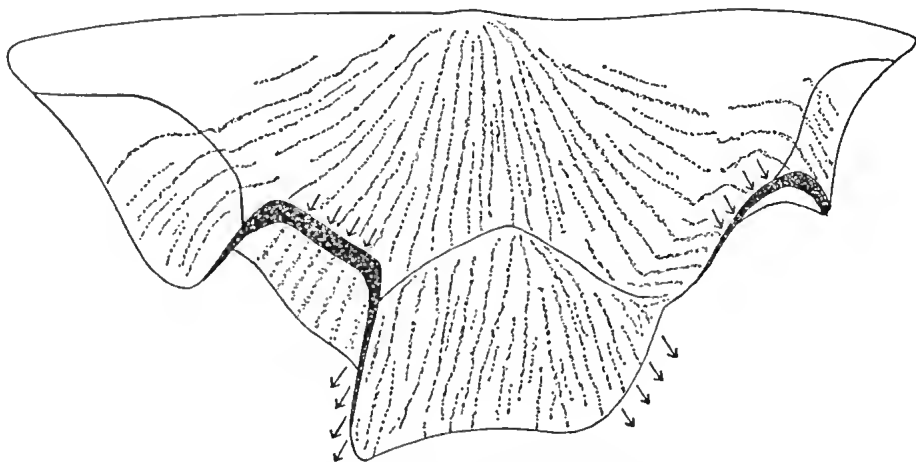


FIG. 8—Outline diagram of *Malurostrophia flabellicauda* with the valves slightly separated. Arrows indicate inferred positions of in- and ex-currents.

(1) the deflecting structures in the median line; (2) the difficulty of separating in- and excurrents on the inner surface of the tongue; (3) the highly significant dorsad deflection of part of the lateral margins in Stage 4 of *Malurostrophia* and *Notoleptaena* (Kozłowski 1929, Pl. 3, fig. 24a, b), isolating a well defined intake sector on each side of the tongue.

#### EVIDENCE OF THE STRUCTURE AND POSITION OF THE LOPHOPHORE AND THE VISCERA

In reconstructing the soft part morphology there are several points to be made initially: (1) The muscles of brachiopods lie within the coelomic cavity, and therefore the inner epithelium of the mantle must pass in front of the anterior edges of the muscle scars. (2) In living articulates, the coelomic cavity is short relative to the total length of the shell, but the high convexity of the shells allows it considerable depth. In plano-convex or concavo-convex shells with a comparable shell surface area (and presumably comparable food and oxygen requirements), the coelomic cavity would have to be relatively longer in order to produce a comparable volume. (3) In living brachiopods, the viscera usually lie suspended behind, between and sometimes partly in front of the adductor muscles. They are usually close to the brachial valve, the stomach being situated behind the mouth which is placed in the brachial groove at the junction of the two arms of the lophophore. The stomach is suspended in position by the gastro-parietal and ilio-parietal bands, and by dorsal and ventral mesenteries. The dorsal is usually the stronger of the two mesenteries, and according to Hancock (1859, p. 813) in the terebratulacean *Waldheimia* 'extends from the dorsal face of the stomach and anterior wall of the chamber to its upper wall, running along from end to end of the septum of the dorsal valve'. The gastro-parietal bands extend backwards to the adductor muscles, and the ilio-parietal bands run laterally to meet the walls of the coelomic cavity at varying positions and over varying distances according to the genus concerned. In addition there is usually a median gastro-parietal band which in *Waldheimia* meets 'the dorsal wall a little in advance of the hinge-plate' (Hancock, p. 813).

Errors in the interpretation of the soft parts of extinct concavo-convex brachiopods have been made in the past by the failure to consider the two valves together. Hollow specimens and thin sections of *Malurostrophia* have shown that: (a) The anterior parts of the transmuscle septa of the brachial valve lie opposite or just lateral to the inner muscle bounding ridges of the pedicle valve, i.e. they lie opposite the inner anterior edges of the diductor muscles (Fig. 1). (b) The so-called brachial ridges (lateral brachial ridges of Harper *et al* 1966) lie opposite the outer anterior part of the diductor muscle bounding ridges in the pedicle valve; and the posterior muscle bounding ridges in the brachial valve are almost flush up against the everted edges of the diductor muscle bounding ridges in the pedicle valve. (c) The anterior tip of the brevisseptum of the brachial valve lies approximately in line with the anterior tips of the diductor scars in the brachial valve.

Similar relationships may be observed in other shallow-bodied strophodontids such as *Nadiastrophia*, *Leptodontella*, and *Zophostrophia* in which these structures are present, but they do not hold for deep-bodied genera.

The opposing relationships of the transmuscle septa and so-called brachial ridges of the brachial valve, and the diductor muscles and muscle bounding ridges of the pedicle valve, indicate that they did not support the lophophore. On the other hand, the transmuscle septa and the inner diductor bounding ridges outline a cavity which is appropriately placed to contain the stomach and intestine, with the dorsal median septum (brevisseptum) marking the line of junction between the

dorsal mesentery and the outer epithelium. The mouth would be situated near the anterior end of the brevisseptum, which is elevated to act as a support for this region where the unsupported lophophore joins the diaphragm. The ilio-parietal bands were probably attached to the wall of the coelomic cavity along the transmuscle septa, and the small triangular median scar at the rear end of the dorsal brevisseptum may mark the area of attachment of the median gastro-parietal band. On this interpretation the 'lateral brachial ridges' would demarcate part of the line along which the inner epithelium turned ventrad to form the wall of the coelomic cavity. The space between the transmuscle septa and the 'lateral brachial ridges' would be occupied, at least in part, by lateral digestive diverticula. If this interpretation be true, the mantle cavity was deeply divided and really consisted of two chambers with maximum height in front, decreasing gradually in height toward the rear where its shape is effectively outlined by the thick marginal ridges. The two chambers are joined by a short passage in front of the mouth.

What feeding devices could utilize a mantle cavity of this shape? There seem to be three possibilities—the circulation of water by rapid opening and closing of the valves and the subsequent entrapment of food particles on mantle cilia which then passed them to the mouth via ciliated mantle tracts; the production of in- and excurrents and the entrapment of food particles by tracts of mantle cilia; and lophophore feeding.

Both of the mantle feeding mechanisms have been rejected. No living forms feed exclusively by mantle cilia. Rudwick (1961, and in Moore 1965), however, has suggested that riebhofeniids used a rapid opening and closing valve mechanism to induce water circulation, food particles being caught on the mantle and perhaps a modified lophophore; and he has further suggested that 'a similar feeding process could have been utilized by many less aberrant productoids, and may even have been characteristic of the whole group'. It seems an unlikely interpretation for *Malurostrophia* because of its very flat mantle cavity which *a priori* would seem not to permit the generation of the necessary eddy currents, the posterior part of the mantle cavity would be 'dead-space', and water would be sucked into the mantle cavity around the entire shell margin including the sectors buried in the substrate. Confirmation of these views by the use of models is desirable. The formation of feeding currents by ciliary tracts on the mantle is improbable because such currents would be very weak, and in any case, there would be no possibility of separating filtered from non-filtered water.

Lophophore feeding is the only remaining possibility. At the early growth stages there seems to be no reason why a trocholophe should not have been present. In living brachiopods these types occur only in juveniles or in small adults. A median incurrent is produced and lateral excurrents pass out around the shell edge, the median incurrent being made possible by a wide shell gape. This could occur in *Malurostrophia* up to the stage of shell deflexion, but beyond that the shape of the median deflexion would obstruct any median incurrent. In any case, if the inferences made from gross shell shape concerning the direction of currents in adults are reliable, the mantle cavity would have to be divided into lateral inhalant chambers and a median exhalant chamber. In living brachiopods such an organization is present only with zygo-plectolophs, plectolophs or spirolophous lophophores. A plectolophe could not effectively occupy a mantle cavity of the *Malurostrophia* type, even allowing that the median spiral could be accommodated.

Recently Cowen and Rudwick (1966) have demonstrated the existence of spiral braehidia in the Jurassic strophomenoid *Cadomella*, which they regard as closely

allied to the concavo-convex Mesozoic spire bearers of the Koninckinidae. The spires in these forms are very flat and arc ventrally directed. The possibility of a similar spirolophe having been present in *Malurostrophia* must be seriously considered, though it is not necessary to conclude that because the members of one small family of Strophomenida bore spirolophes, those of all the other constituent groups did likewise. The Koninckinacea is thought to be a Mesozoic offshoot from the Chonetacea, a superfamily that was already distinct from the Strophomenacea (to which *Malurostrophia* belongs) in the late Ordovician. This long independent history leaves ample scope for the development of diverse characters and in this respect it is important to note that not all the Koninckinacea have the typical strophomenidine shell tissue structure. Only the Koninckinacea among the Strophomenidina survived the end of the Palaeozoic, and it is not impossible that it was the assumption of a spirolophe that enabled them to succeed.

The mantle cavity in *Malurostrophia* was only about 1 mm high in adults with the shell closed. There is no evidence that the shell gaped widely during feeding; on the contrary, the geometry of the marginal deflexions and internal ridges suggests

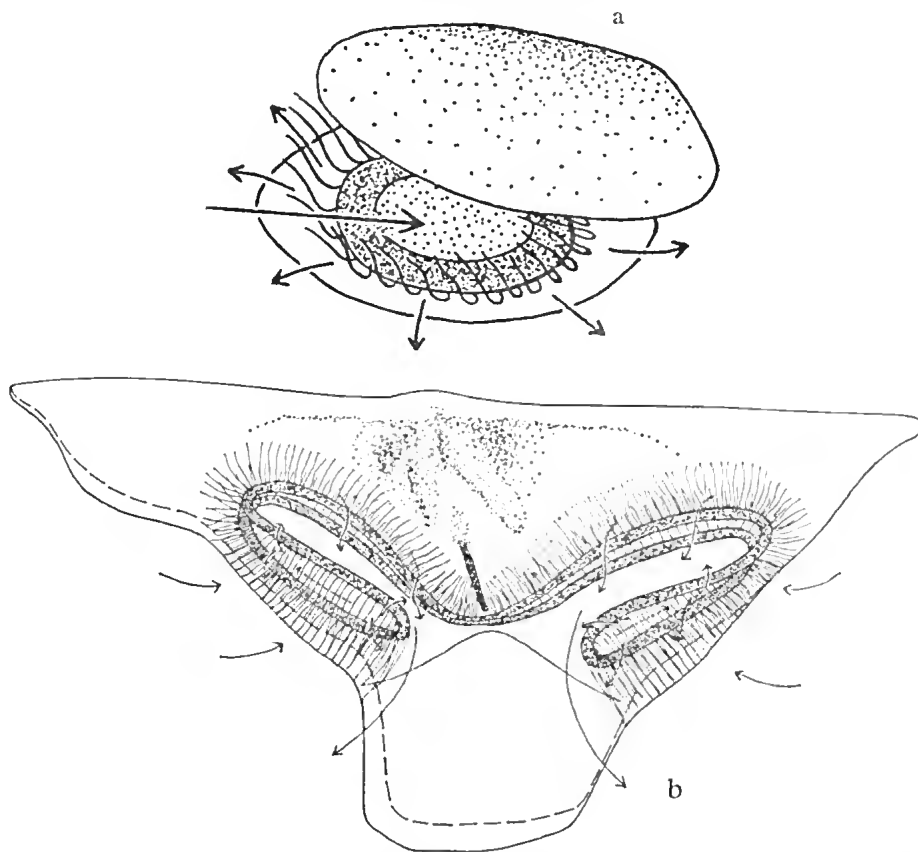


FIG. 9—(a) Reconstruction of the trocholophous early growth stage of *Malurostrophia flabellicauda*. (b) Reconstruction of the zygolophous adult stage showing the disposition of the lophophore and the flow pattern of the feeding currents. Upper (pedicle) valve outlined by dashes.



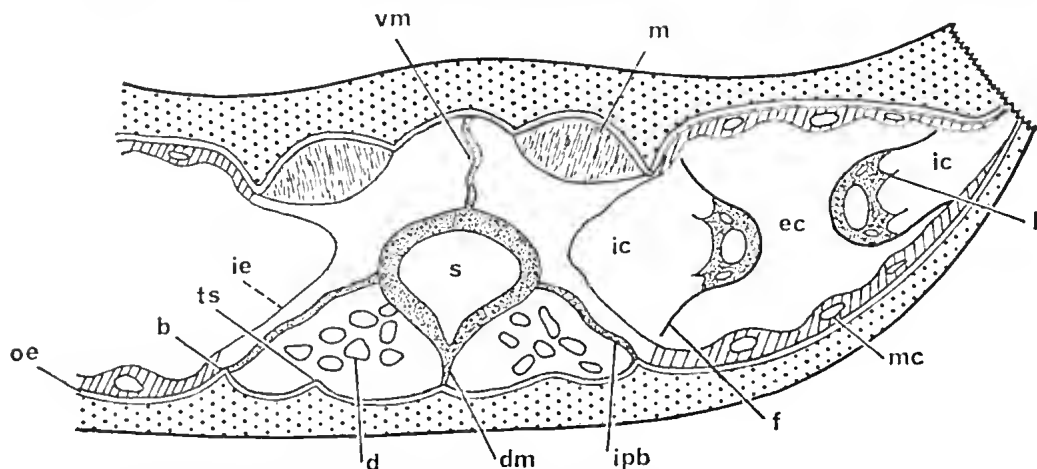


FIG. 10—Diagrammatic reconstruction of a transverse section taken across *Malurostrophia flabellicauda* between the anterior edges of the adductor and diductor muscles in the pedicle valve. b = 'lateral brachial ridge'; d = digestive diverticula; dm = dorsal mesentery; ec = exhalant chamber of mantle cavity; f = filament of lophophore; ie = inhalant chamber of mantle cavity; ie = inner epithelium of mantle; ipb = ilio-parietal band; l = lophophore lip; m = diductor muscle; mc = mantle canal; oe = outer epithelium; s = stomach; ts = transmuse septum; vm = ventral mesentery.

that the gape was slight. In any case, even if it reached  $25^\circ$ , the maximum height of the mantle cavity in life would have been less than 1.5 mm, and that towards its front. The ventral surface of each mantle cavity would have been rather flat and not arched to receive the apex of a spire. Each chamber would also be only 2.0-2.5 by 4.0-4.5 mm in most adults. A spire occupying a cavity with these dimensions would be similar in size to those formed shortly after metamorphosis from a schizolophe in modern rhynchonellaceans (Rudwick 1962). Further, a spire effectively occupying a cavity with such an irregular bean-like outline (see Pl. 47, fig. 15) would need a more complicated outline than that of such forms as *Cadomella*.

None of these objections to a spirolophe is conclusive. On the other hand there is no really persuasive evidence in favour of such a reconstruction, either for *Malurostrophia* or for any other Palaeozoic Strophomenacean. However, another reconstruction commends itself more than does a spirolophe. A zygo-lophe oriented in the manner shown in Fig. 9 would satisfy all the known requirements. Its maximum incurrent and excurrent pressures would be appropriately placed, the flat bean-shaped mantle chambers would be effectively occupied, the inhalant and exhalant chambers would be neatly separated, the brachial arms would be free of valves and leave no impression on the shell, and the high point at the anterior end of the median septum could be interpreted as their only support (apart perhaps from spicules). The size of the shell is no objection, since in recent genera zygo-lophes are known, even in such deep bodied forms as *Fallax*, at shell lengths up to 54 mm (Atkins 1960). The fact that zygo-lophes are at present known only in the Terebratulida is not regarded as contrary evidence, since the more complex spirolophe is known to have developed independently at least three times, and our knowledge of two of these evolutionary events is based on rarely occurring early Mesozoic genera (Cowen & Rudwick 1966, p. 406).

This interpretation differs fundamentally from that offered by Williams (in Moore 1965) and Harper *et al* (1966) for genera of the Strophomenacea. Application of a similar line of argument would also require drastic revision of the lophophore reconstructions of some of the productaccans and plectambonitaccans offered by Williams & Rowell (in Moore 1965, p. 107).

TABLE 1

*Dimensions (mm) of Malurostrophia flabellicauda sp.nov., arranged in growth series*  
A. BIVALVED SPECIMENS

Length	Breadth	Height Tongue	Height ped. interarea	Height br. interarea
1. <i>Receptaculites</i> Limestone, Bloomfield Station, Taemas, N.S.W.				
5.8	8.4	1.9	0.35	0.22
6.1	11.4	—	0.45	0.25
7.0	11.0	3.6	0.55	0.32
7.4	10.8	4.0	0.55	0.32
7.4	11.0	4.2	0.60	0.35
7.8	11.4	4.0	0.55	0.30
2. Crinoidal Limestone, Hume Park, N.S.W.				
6.2	9.8	4.7	0.50	0.2+
6.6	11.0	5.0	0.55	0.25
3. Murrindal Limestone, Rocky Camp Ridge, Buchan, Victoria				
4.5	7.6	—	—	0.20
4.5	7.8	1.7	—	—
4.5	8.2*	3.2	0.40	0.15
4.8	8.4*	2.1	0.30	0.20
5.1	8.9	2.1	0.35	0.20

B. ISOLATED PEDICLE VALVES—*Receptaculites* Limestone,  
Bloomfield Station, Taemas, N.S.W.

Length	Breadth	Width of Denticulation Ped. Valve	Max. Length Muscle Field Ped. Valve	Max. Width Muscle Field Ped. Valve	Length Hinge to Median Node	Length Adductors	Width Adductors
—	5.3	2.2	0.8	1.1	—	—	—
—	7.2	3.2	1.3	1.6	4.0	—	0.6
—	a8	3.6	1.6	2.0	4.3	0.7	1.0
6.0	a10	5.5	2.7	2.3	4.0	1.4	1.2
6.0	10.5	5.2	2.1	2.4	4.3	1.0	1.1
6.5	a12	6.2	2.6	2.3	4.3	1.2	1.3
6.5	12.0	7.0	2.8	2.7	4.5	1.6	—
7.0	12.5	6.5	3.3	3.1	4.5	1.2	1.5
7.2	12.8	5.1	2.5	2.5	4.9	1.1	1.0
7.5	12.4	6.6	3.2	2.8	4.8	—	1.3
7.5	12.5	6.5	3.1	2.7	4.6	1.3	1.2
7.5	14.4	—	3.4	3.2	5.0	—	1.4
8.0	a13	7.6	3.5	2.7	5.0	1.2	1.5
8.0	15.0	7.0	2.7	2.7	5.5	1.7	1.2
8.2	a20	9	4.0	3.2	6.0	1.8	2.0
8.5	a17	8.5	4.0	3.5	5.2	1.5	1.4

C. ISOLATED BRACHIAL VALVES—*Receptaculites* Limestone,  
Bloomfield Station, Taemas, N.S.W.

Length Hinge to Point of Deflection	Breadth	Height Tongue	Width Cardinal Process Lobes	Width Muscle Field of Br. Valve	Length Hinge to Anterior end of Ant. Adductors	Length Socket Plates	Length Strongly Expressed Muscle- bounding Ridges
—	5.3	—	0.1 <sub>2</sub>	1.1	a2.0	0.2	0.2 <sub>5</sub>
—	5.1 <sub>5</sub>	—	0.1 <sub>2</sub>	—	—	0.3	0.3
—	—	—	0.2 <sub>2</sub>	1.1	2.9	0.5	0.6
5.3	—	2.5	0.5 <sub>0</sub>	1.9	3.7	1.1	1.1
5.5	10.9*	1.0	0.4 <sub>2</sub>	1.9 <sub>5</sub>	3.3	1.1	0.9
5.0	—	2.2	0.3 <sub>5</sub>	2.0	a4.0	1.0	1.0 <sub>5</sub>
5.1	11.4*	1.9	0.6 <sub>2</sub>	2.0 <sub>5</sub>	—	1.0	1.0
5.0	11.9	—	0.4 <sub>5</sub>	2.0	3.5	1.0	1.0
5.3	11.4*	2.6	0.5 <sub>5</sub>	—	—	0.8	1.1
5.3	11.4*	2.3	0.5 <sub>0</sub>	2.1	4.1	0.8	1.1
5.7	—	1.9	0.4 <sub>5</sub>	2.2	3.6	0.8	1.2
—	—	—	0.5 <sub>5</sub>	2.2	—	1.0	1.2
5.0	—	—	0.4 <sub>0</sub>	2.2 <sub>5</sub>	3.6	1.0	1.2
5.0	—	2.7	0.5 <sub>0</sub>	2.1	3.9	1.2	1.1
5.6	12.2	2.6	0.7 <sub>0</sub>	2.3	4.1	1.2	1.3
—	12.5*	—	0.4 <sub>5</sub>	2.3	4.0	1.2	1.2 <sub>5</sub>
5.2	12.8*	3.7	0.6 <sub>0</sub>	2.7	3.8	1.2	1.1 <sub>5</sub>

a = approximate

\* = measurement of breadth derived by doubling  
measurement from midline to an unbroken alation

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### Explanation of Plates

The symbol ANU refers to collections of the Department of Geology, School of General Studies, Australian National University, Canberra; GSV refers to the fossil collections of the Geological Survey, Mines Department, Melbourne.

#### PLATE 47

Fig. 1-5, 8-16,  $\times 4$ ; Fig. 6, 7,  $\times 3.4$ .

- Fig. 1-16—*Malurostrophia flabellicauda* gen. et sp. nov. 1-3, 6—dorsal, ventral, posterior and antero-ventral views respectively of holotype, ANU 14620. 4, 5—ventral and dorsal views respectively, ANU 14623; note the dorsal node and the greater density of costellation on the tail. 7—antero-dorsal view, ANU 14639. 8-15—growth series of pedicle valves, ANU 14630, 14629, 14633, 14627, 14628, 14622, 14624, 14614 respectively, showing the lack of defined musculature in the smallest available specimens, the cordate muscle field with diductors initially directed at right angles to each other but tending progressively towards sub-parallelism, the presence of a defined ventral process even in juvenile specimens, and the presence of strong vascula dentalia and a well defined marginal ridge on the interior of mature specimens (Fig. 13-15). 16—oblique postero-dorsal view, ANU 14635 to show the greater density of grooves on the inner surface of the tail compared with that of the ventrally deflected antero-lateral margins.

All specimens from the *Receptaculites* Limestone, Bloomfield Station, Tarnas, N.S.W.

#### PLATE 48

Fig. 1-3, 5-10, 12-16, 19-20,  $\times 4$ ; Fig. 4,  $\times 6$ ; Fig. 11,  $\times 3.4$ ;  
Fig. 17,  $\times 20$ ; Fig. 18,  $\times 25$ .

- Fig. 1-20—*Malurostrophia flabellicauda* gen. et sp. nov. 1-2—antero-lateral and internal views of a large brachial valve showing the high antero-medial thickening, ANU 14983. 3, 4—internal and posterior views of a gerontic brachial valve showing the thickened adductor scars and a small median scar, and the posterior face of the cardinal process and chilidium, ANU 14986. 5, 9, 12-14—internal views of four brachial valves showing variations in the differentiation of the adductor scars and size and outline of the transmuscle septa; 14 is the youngest individual, ANU 14985, 14619, 14982, 14617, 14625. 6—lateral view of part of 7 to show the pallial markings. 10—posterior view of 9. 11—anterior view of a gerontic individual showing the high antero-medial thickening, ANU 14653. 15-16—internal and postero-lateral views of a large pedicle valve showing the reflected margins in front of the ears, ANU 14989. 17—dorsal view of a small individual showing the pedicle foramen, ANU 14993a. 18—internal view of a small individual in which the shell has been partly removed to expose the pedicle tube, ANU 14993b (subsequently broken). 19, 20—lateral and oblique views of a large complete individual to show the gross shape, ANU 14990.

All specimens from the *Receptaculites* Limestone, Bloomfield Station, N.S.W.

#### PLATE 49

Fig. 1-2,  $\times 10$ ; Fig. 3,  $\times 23$ ; Fig. 4-8,  $\times 4$ ; Fig. 9-11,  $\times 1.5$ .

- Fig. 1-8—*Malurostrophia flabellicauda* gen. et sp. nov. 1-3—stereo-pairs of cardinalia and

muscle-bounding ridges of young specimen, ANU 14625, and mature specimen, ANU 14619; and postero-dorsal view of cardinal process lobes and palintrope of mature specimen, ANU 14626; note the dentition resembling a slotted groove (Fig. 2), the narrow notothyrium covered by the concave chilidium (Fig. 3), and the lobate nature of the attachment faces of the cardinal process lobes (Fig. 2 & 3). 4-8—oblique posterior and lateral views of four pedicle valves to show the variation in shape of the muscle field, the everted muscle bounding ridges, the mantle canal system, particularly the vascula dentalia and the vascula media; Fig. 4, 8, ANU 14622, Fig. 5, ANU 14621, Fig. 6, 7, ANU 14987.

Fig. 9-11—*Notoleptaena* sp. nov. 9-10—dorsal and oblique views of an almost complete specimen, GSV 61828. 11—ventral view of a partly eroded specimen, GSV 61829.

*M. flabellicauda* from *Receptaculites* Limestone, Bloomfield Station and *N. sp. nov.* from the Taravale Formation, locality 16, Bindi, Victoria (same locality as *M. basilica*).

#### PLATE 50

Fig. 1-7, 13,  $\times 3.5$ ; Fig. 8-10,  $\times 5$ ; Fig. 11, 12,  $\times 1.5$ .

Fig. 1-7—*Malurostrophia basilica* gen. et sp. nov. 1-5—dorsal, ventral, posterior, lateral, and anterior views respectively of holotype GSV 58553; note the grooving of the dorsal and ventral palintropes corresponding to the dentition, and the less parvicostellate ornament compared with *M. flabellicauda*. 6—internal mould of brachial valve of paratype GSV 58554 prepared by calcining and scraping; note the general resemblance to the brachial interior of *M. flabellicauda* except for the more sinuous transmuscle septa (brace plates). 7—internal mould of pedicle valve of same specimen, prepared by calcining and scraping; note the strong ridges bounding the adductor muscle field.

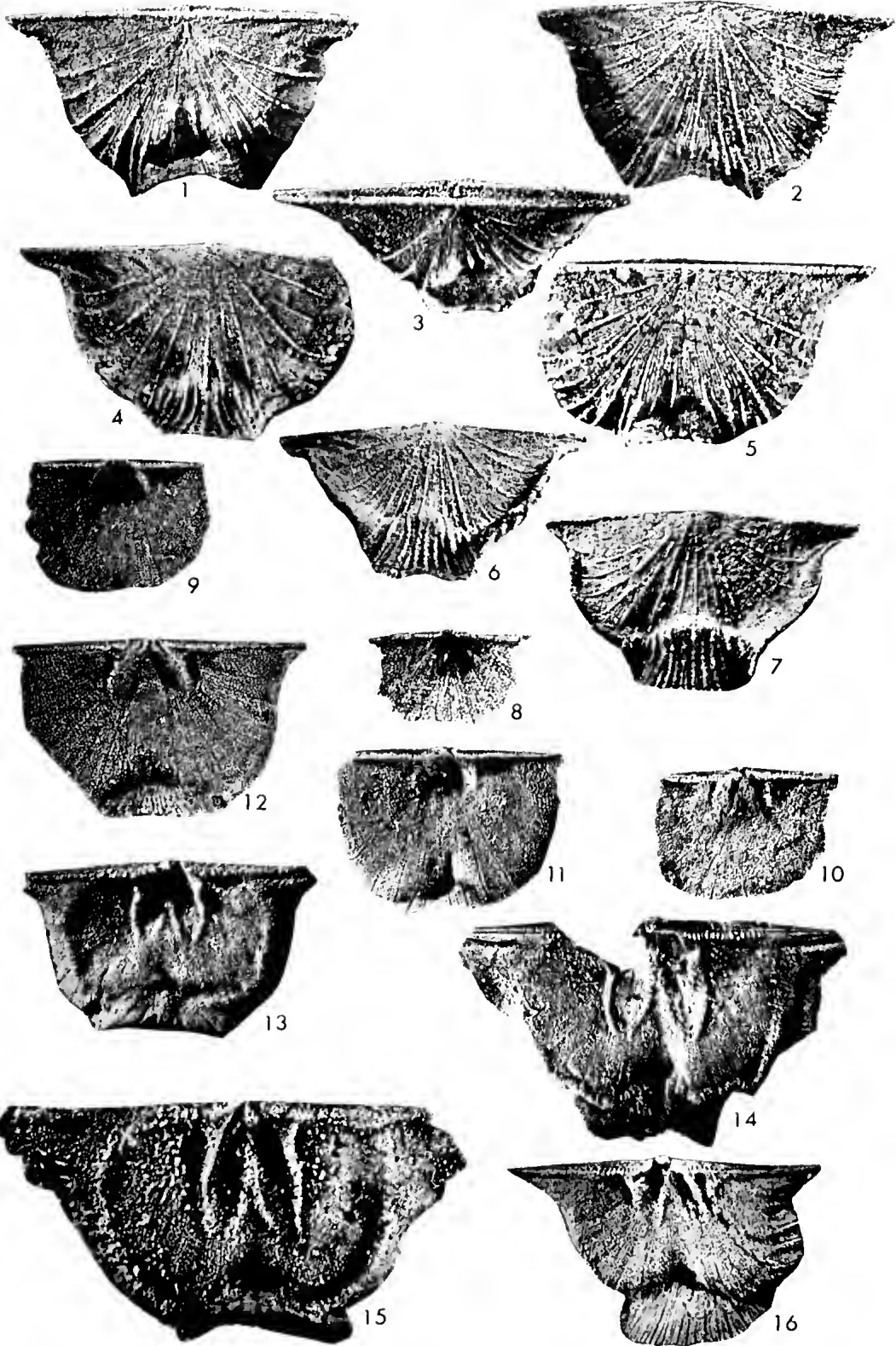
Both specimens from the Taravale Formation, locality 16, Bindi, Victoria.

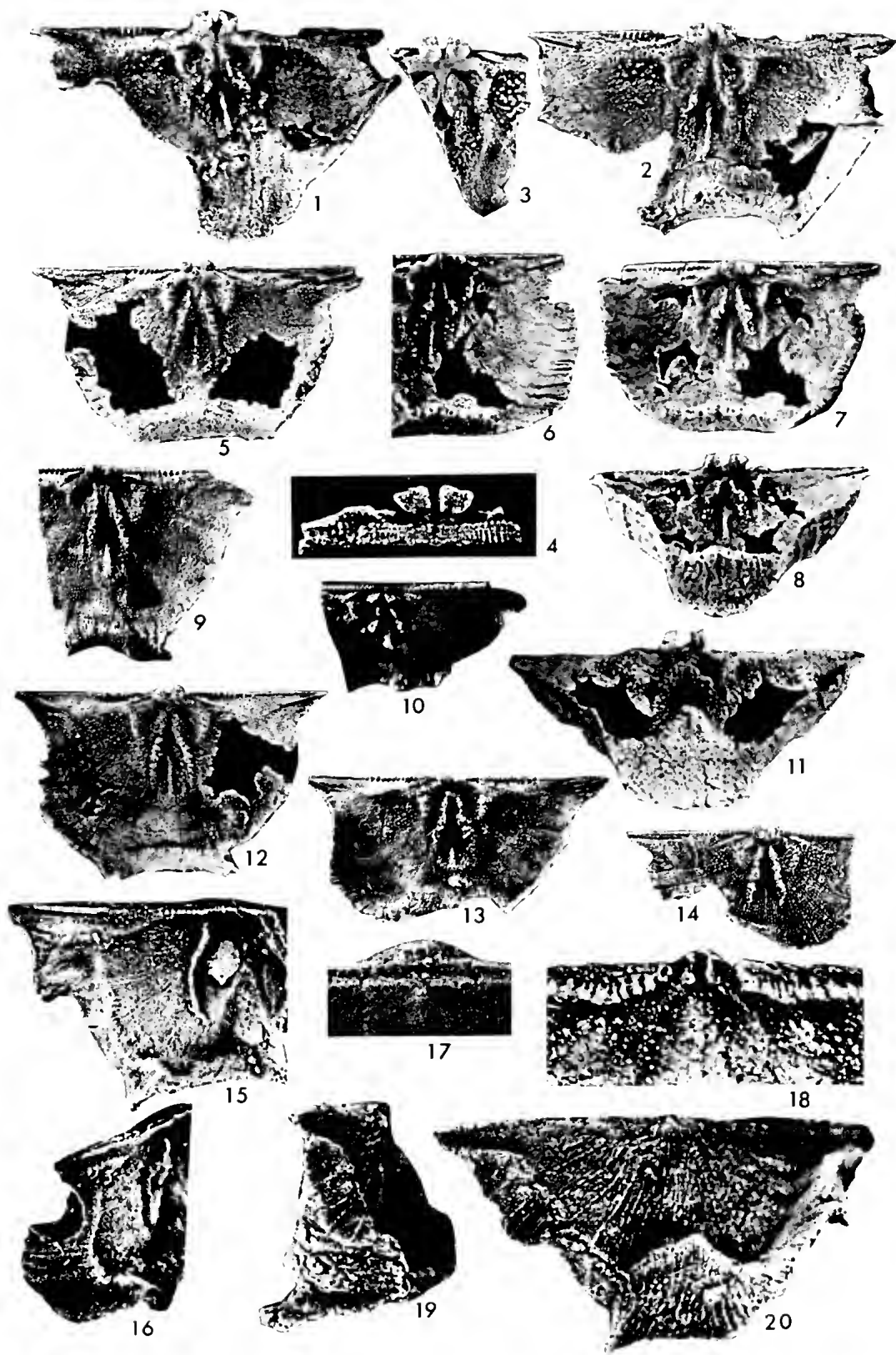
Fig. 8-10—*Malurostrophia flabellicauda* gen. et sp. nov. 8, 9—ventral and oblique lateral views of GSV 58552; note the pronounced costellation and the prominent median node; 10—ventral view of GSV 58551; note the primary deformation of the specimen.

Both specimens from the *Calceola* band of the lower Murrindal Limestone on the crest of the ridge running east from Rocky Camp, Buchan, Victoria.

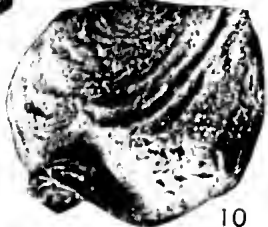
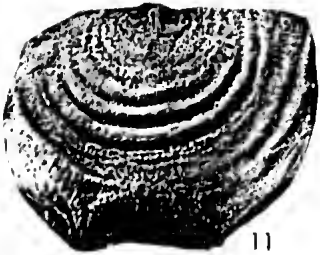
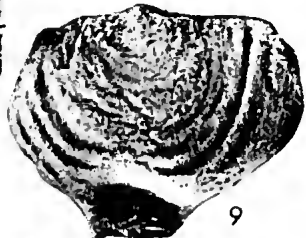
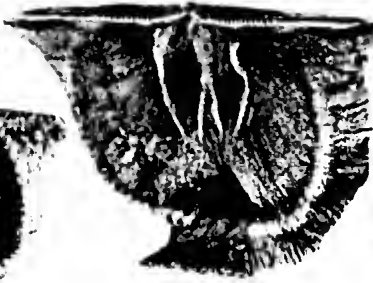
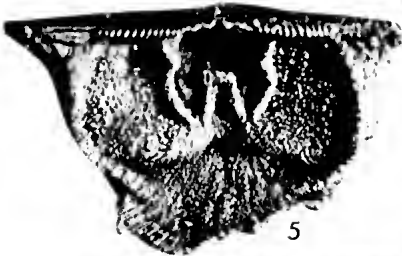
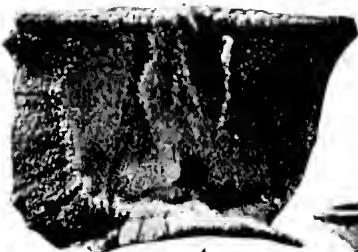
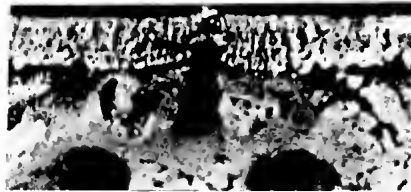
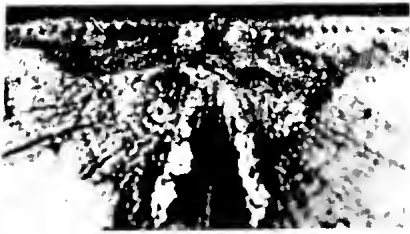
Fig. 11-13—*Leptodontella caudata* (Schnur). 11—plaster replica (internal mould) of pedicle valve, GSV 58549—original in the Schultz Collection, Museum of Comparative Zoology, Harvard University, U.S.A.; contrast the flabellate musculature with that of *M. basilica* (Fig. 7) and *M. flabellicauda* (Pl. 1 and 2). 12, 13—rubber mould of brachial interior, and enlargement of musculature and cardinalia, GSV 58550—original in the collections of the U.S. National Museum, Washington, U.S.A.; contrast the musculature and muscle-bounding ridges with those of *M. basilica* (Fig. 6) and *M. flabellicauda* (Pl. 2).

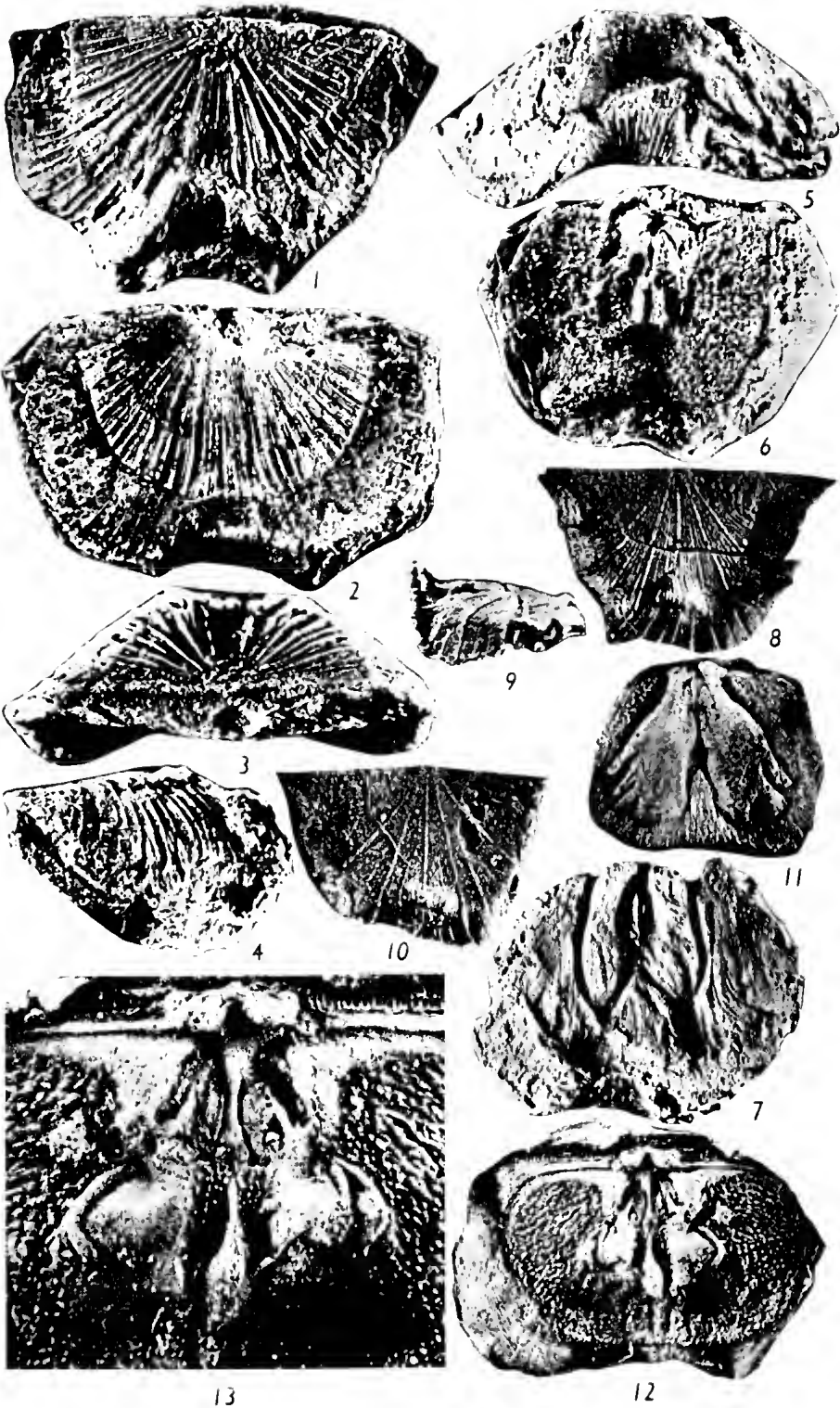












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Glaessner, M. F., PhD DSc, FAA, Geology Dept, University of Adelaide, S.A.	1939
Hill, Prof. Dorothy, DSc PhD, FAA, Geology Dept, University of Queensland, St Lucia, Q.	1939
Kershaw, R. C., BSc, 45 West Tamar Rd, Launceston, T.	1956
McWhae, Mrs K. M., MSc, 16 Goldsmith Rd, Claremont, W.A.	1948
Netherway, G. C., 606 Dana St, Ballarat	1958
Payne, T. E. N., 'Woodburn', Kilmore	1945
Rowe, R. K., BScFor, 17 Brody St, Wangaratta	1965
Searle, S. S., Metropolitan Farm, PO, Werribee	1954
Yates, H., MSc, 102 Eyre St, Ballarat	1943

## ASSOCIATES

Anderson, R. E., BA, 20 Hudson St, Moonee Ponds, W4	1964
Autry, W. C., BSc, 4446 SW Kenyon Pl., Seattle, Washington, 98116, U.S.A.	1957
Baker, A. A., 53 Carlisle St, Preston, N18	1946
Bamford, W. E., BE (Hons), 190 Page St, Middle Park, SC6	1963
Beavis, Mrs J. H., 112 Kanooka Gr., Clayton	1965
Bird, R. G., 112 Prince Alfred Pde, Newport, N.S.W.	1962
Bollen, P. W., BSc, 5 Mercer Rd, Armadale, SE3	1957
Bowen, K. G., BSc, 2 Burke St, Montmorency	1966
Bowler, J. M., MSc, Geography Dept, Research School of Pacific Studies, ANU, Canberra, A.C.T.	1960
Brine, F. W., 'Taunton', Oakdene Court, Mt Waverley	1964
Brunn, Mrs T. H., 605 Malvern Rd, Toorak, SE2	1960
Buckingham, H. L., Farrell St, Ouyen	1965
Buttery, S. H., 146 Highfield Rd, Camberwell, E6	1952
Carr, Mrs D. J., MSc, Queen's University, Belfast, N. Ireland	1937
Carter, A. N., MSc PhD, 8 Scott St, Maroubra Bay, N.S.W.	1947
Clarke, W. G., BE BSc DipEd, 2 Meeks Cres., Faulconbridge, N.S.W.	1957
Clifford, H. T., MSc PhD, Botany Dept, University of Queensland, St Lucia, Q.	1949
Cobbett, A. M., Oxford Close, Moorabbin, S20	1951
Cochrane, G. W., MSc, 320 Lane St, Broken Hill, N.S.W.	1945
Colledge, Miss J. S., 51 Through Rd, Burwood	1964
Cormack, M. G., Lower Crawford, Private Bag 39, P.O. Heywood	1961
Couper, J. K., FRMIT, C/- Hare & Assoc., 19 Hamilton St, Sydney, N.S.W.	1965
Court, A. B., BSc, National Herbarium, Royal Botanic Gardens, South Yarra, SE1	1949
Coventry, A. J., National Museum of Victoria, Russell St, Melbourne, C1	1966

Davies, A. F., Wayside Delivery, Bridgewater Rd, Portland	..	..	..	..	1965
de Jonk, B. T. R., 21 Mall Court, Blackburn N.	..	..	..	..	1964
Elford, F. G., BSc BEd, 76 New St, Brighton, S5	..	..	..	..	1929
Elmore, L. K. M., PO Box 317, Hamilton	..	..	..	..	1964
English, J. R., 302 Lower Heidelberg Rd, E. Ivanhoe, N21	..	..	..	..	1956
Finlay, Miss C. F., BSc, Geology Dept, University of Melbourne, Parkville, N2	..	..	..	..	1950
Fisher, Eileen E., PhD, 1 Balwyn Rd, Canterbury, E7	..	..	..	..	1949
Frostick, A. C., 12 Power St, N. Williamstown, W16	..	..	..	..	1933
Gamble, D. S., 6 Gellibrand St, Kew, E4	..	..	..	..	1964
Gostin, V. A., BSc MSc, Geology Dept, ANU, Canberra, A.C.T.	..	..	..	..	1963
Hatton, H., 55 Hunt Cres., Ascot Vale, W2	..	..	..	..	1965
Hewett, D. C., BSc DipEd, 17 Victoria Av., Macleod W.	..	..	..	..	1959
Hounslow, A. W., BSc, 28 Georgiana St, Sandringham, S8	..	..	..	..	1958
Johns M. W., BSc, MB BS, Alfred Hospital, Commercial Rd, Prahran	..	..	..	..	1958
Jones, B. C., 34 Boyana Cres., Croydon	..	..	..	..	1965
Lawrence, C. R., BSc, 4 Una St, Mt Waverley	..	..	..	..	1958
Lord, E. E., 16 Salisbury Court, Heathmont	..	..	..	..	1950
McLaurin, A. N., Couangalt, via Gisborne	..	..	..	..	1963
McLennan, Assoc. Prof. Ethel, DSc, Botany Dept, University of Melbourne, Parkville, N2	..	..	..	..	1915
Marsden, M. A. H., BSc, Geology Dept, University of Melbourne, Parkville, N2	..	..	..	..	1952
Matthaci, Mrs G., BA DipEd, Geology Dept, University of Melbourne, Parkville, N2	..	..	..	..	1959
Mooney, M. J., 'Beann Nhairi', Yarra Junction	..	..	..	..	1963
Moors, H. T., BSc, Geology Dept, University of Melbourne, Parkville, N2	..	..	..	..	1965
Neilson, J. L., BSc, 55 Glyndon Rd, Camberwell, E6	..	..	..	..	1952
Nicholson, B. M., BAgSc, Soil Conservation Authority, Box 187 PO, Bairnsdale	..	..	..	..	1963
Niksic, N., ARACI DipEng Zagreb, 5 Vaughan Ave, Canterbury	..	..	..	..	1966
Passioura, J. B., MSc PhD, CSIRO Land Research, P.O. Box 109, Canberra City, A.C.T.	..	..	..	..	1961
Pinches, Mrs M., 140 Churchill Highway, Braybrook, W19	..	..	..	..	1943
Poole, I. R., 27 Glen Ebor Ave, Blackburn	..	..	..	..	1966
Pretty, R. B., MSc, Private Bag, Cobargo, N.S.W.	..	..	..	..	1922
Rash, K. E., 519 Humffray St S., Ballarat	..	..	..	..	1960
Rawlins, R. J., BSc, P.O. Box 2, Herberton, Q.	..	..	..	..	1957
Reed, K. J., BSc, C/- Nigerian Gulf Oil Co., PMB 2469, Lagos, Nigeria	..	..	..	..	1958
Rimington, K. N., BSc, 15 Yuille St, Brighton, S5	..	..	..	..	1948
Seebeck, J. H., BSc, Flat 2, 67 Lisson Grove, Hawthorn	..	..	..	..	1967
Shaw, H., 16 Douglas Av., Box Hill S.	..	..	..	..	1956
Sherrard, Mrs H. M., MSc, 43 Robertson Rd, Centennial Park, N.S.W.	..	..	..	..	1918
Simpson, B., 3 Knutford St, Balwyn, E8	..	..	..	..	1959
Sinnott, P. J., 17 Normdale Rd, E. Bentleigh, SE15	..	..	..	..	1959
Spry, Miss Elaine M., BSc, Geology Dept, University of Melbourne, Parkville, N2	..	..	..	..	1966
Stone, A. G., 24 Alandale Rd, Eaglemont, N21	..	..	..	..	1965
Stone, Mrs I. G., MSc PhD, 24 Alandale Rd, Eaglemont, N21	..	..	..	..	1965
Stubbs, D., 2 Coleridge St, Elwood, S3	..	..	..	..	1960
Taylor, T. W., Dept of Works, Katherine, Northern Territory	..	..	..	..	1963
Tuddenham, W. G., BSc DipEd, Geography Dept, University of Sydney, NSW	..	..	..	..	1963
Vandenberg, A. H. M., 6 Frew Av., Frankston	..	..	..	..	1965
Vasey, G. H., BCE, Dept Agric. Engineering, University of Melbourne, Parkville, N2	..	..	..	..	1936
Walker, A. L., Division of Mineral Chemistry, CSIRO, Garden City	..	..	..	..	1961
Walsh, Mrs A., C/- Australian College of Education, 916 Swanston St, Carlton, N3	..	..	..	..	1964
Watts, H. A., 15 Tower Hill Rd, Glen Iris, SE6	..	..	..	..	1954
White, O. L., BSc MSc, Dept of Civil Engineering, University of Waterloo, Waterloo, Ontario, Canada	..	..	..	..	1955
Whitehead, Mrs R., MSc, C/- Anaconda Aust. Inc., 208 Hutt St, Adelaide, S.A.	..	..	..	..	1942
Wilkins, R. W. T., MSc PhD, Hoffman Laboratory, Harvard University, Cambridge, Mass., U.S.A.	..	..	..	..	1961

## LIST OF MEMBERS AND ASSOCIATES

Wilkinson, H. E., National Museum, Russell St, Melbourne, C1	..	..	..	1965
Williams, G. E., MSc PhD, Geology Dept, University of Adelaide, S.A.	..	..	..	1962
Williams, Mrs J. F. H., C/- 8 Montague St, Highton, Geelong	..	..	..	1962
Wymond, A. P., MSc, CSIRO Division of Forest Products, PO Box 18, S. Melbourne,	SC4	..	..	1951

# Royal Society of Victoria

## ANNUAL REPORT OF THE COUNCIL FOR 1966

The President and Council present to Members of the Society the Annual Report with Financial Statement for the year 1966.

The following meetings of the Society were held:

MARCH 10—ANNUAL MEETING. The following office-bearers were elected:

*President:* Mr J. H. Chinner.

*Vice-Presidents:* Dr P. G. Law, Professor C. M. Tattam.

*Hon. Secretary:* Dr F. C. Beavis.

*Hon. Treasurer:* Mr L. Adams.

*Hon. Librarian:* Professor C. M. Tattam.

*Hon. Assistant Secretary:* Mr D. S. Woodruff.

During the year, following amendments to the Society's laws, Professor G. W. Loeper, the Hon. Editor, and Mr E. D. Gill, the Research Secretary, joined the Council as office-bearers.

The following members of Council were elected:

Professor J. Andrews, Mr H. C. Chipman, Professor J. D. Morrison, Dr C. E. Resch, Mr A. D. Butcher, Dr D. E. Thomas.

The following members of Council continued in office:

Mr V. G. Anderson, Dr B. D. Cuming, Dr R. R. Garrahan, Professor J. S. Turner, Mr R. T. M. Prescott, Professor G. C. Schofield.

Upon conclusion of the Annual Meeting an Ordinary Meeting was held. Professor K. E. Bullen was awarded the Society's 1965 Research Medal and following the presentation Professor Bullen spoke on 'Researches on the Earth's Interior'.

Further ordinary meetings were held on:

APRIL 14—'Conservation of Land and Water Resources in Israel' by Mr R. G. Downes.

MAY 12—'Micrometeorology' by Dr D. E. Angus.

JUNE 9—'Treebreeding and Cytogenetic Research in *Pinus radiata*' by Mr L. A. Pedrick.

JULY 14—Research papers were presented by: M. J. Littlejohn and A. A. Martin, F. C. Beavis, D. Spencer-Jones, A. M. Gill and D. H. Ashton, K. G. McKenzie, F. I. Norman, A. E. H. Pedder, T. W. Hogan, J. Goodie, A. J. Boucot and J. G. Johnson, and E. D. Gill.

AUGUST 11—'The Training of Science Teachers' by Mr K. Lee Dow.

SEPTEMBER 8—'Genetics and Biochemistry' by Professor F. J. R. Hird.

OCTOBER 13—'Chemotaxonomy of Eucalypts' by Dr W. E. Hillis.

NOVEMBER 10—*Soirée*. A wide range of scientific exhibits were presented and three films screened.

DECEMBER 8—Research papers were presented by: P. A. Rawlinson, R. S. Frankenburg, K. S. W. Campbell and J. A. Talent, F. I. Norman, R. J. Pyror, H. J. Fearn-Wannan, A. Neboiss, K. Sherrard, I. C. Cookson and A. Eisenack, and E. D. Gill.

The number of members at 31 December 1966 was: Honorary 2, Life Members 23, Members 355, Associates 85, and Country Members 18, making a total of 483.

Captain John King Davis, CBE, FRGS, was elected Life Member—*Honoris causa*—for his long and exceptional service to the Society.

During the year 2,708 volumes and parts were added to the Library.

Attendances at Council meetings were: Mr Adams 4, Mr Anderson 9, Professor Andrews 0, Dr Beavis 8, Mr Butcher 4, Mr Chinner 10, Mr Chipman 6, Dr Cuming 2, Dr Garran 3, Mr Gill 5, Dr Law 4, Professor Leeper 8, Dr Morrison 9, Mr Pescott 3, Dr Resch 1, Professor Schofield 1, Mr Woodruff 10.

During the year, Mr Adams, Mr Gill, Professor Schofield, Dr Law, Dr Garran and Dr Cuming were granted leave of absence overseas. During Mr Gill's absence Dr Spencer-Jones was Acting Research Secretary, and Professor Morrison was Acting Treasurer during Mr Adams's absence.

#### MINUTE OF APPRECIATION

Mr F. G. ELFORD resigned from Assistant Editorship in 1966, after eleven years of service with the Society. During this time he produced 22 parts of the *Proceedings*, comprising 12½ volumes. These included 3 Symposia: on the Victorian High Plains, the Basalt Plains of Western Victoria, and the Victorian Mallee. He also edited the Author Index for Vols. 47-70, issued with Vol. 73, 1961. The Council wishes to record its appreciation of his extremely careful and efficient work on the Society's behalf, and regrets that pressure of his extended duties in the University of Melbourne as Deputy Registrar eventually compelled him to resign.

The Society deeply regrets the loss during the year of the following members:

WILLIAM BARAGWANATH was born at Durham Lead near Ballarat in 1878 and died in Melbourne in 1966. After attending the Ballarat School of Mines he was articled to Robert Allan, Land and Mining Surveyor of Ballarat, from 1894 to 1897, and then joined the Geological Survey staff of the Mines Department of Victoria. He carried out many geological surveys of goldfields, beginning with Walhalla, and during this period he continued his studies in surveying and geology. In 1916 he was moved to the Morwell district and there accumulated much of the information that was later used by the State Electricity Commission in establishing the open-cut mine for brown coal. In 1922 he became Director of Geological Survey and in 1924 Chief Mining Surveyor. He retired from the post of Director in 1943, but was retained as a geological consultant until 1950. His eighty scientific publications, mainly of the Department of Mines, include four Memoirs and eight Bulletins of the Geological Survey. For his services to the mining industry and the geological sciences he was awarded the Order of the British Empire in 1952. He was a member of the Royal Society of Victoria from 1922 until his death. He was a member of the Council from 1940 and President in 1944-45.



THOMAS MACFARLAND CHERRY was born in Melbourne in 1898 and died on 21 November 1966. He was educated at Scotch College and Melbourne University, then went to Cambridge where, in 1924, he was awarded the PhD for his mathematical work. He returned to Melbourne to become Professor of Mathematics in 1929. His mathematical studies won him great distinction. He was awarded ScD of Cambridge in 1950 and became an FRS in 1954. He was a founder of the Australian Academy and became its President in 1961. He was a founding member of the Australian Mathematical Society in 1956 and its first President. After his retirement from the Chair in 1963 he kept on with his work and recently returned from a visiting professorship in Seattle, U.S.A. He was made KCB in 1965. He was a member of the Royal Society of Victoria from 1930 until his death.

THOMAS WILLIAM CRAWFORD was born in Melbourne in 1944, and died on 22 October 1966. During his short life he had established himself as an outstanding collector and was an active member of societies in the natural sciences. As a boy he had imported and propagated rhododendrons and rare orchids in his own hot-house, and he had explored the rhododendron forests of India and Kashmir shortly before his death. He was an associate member of the Royal Society of Victoria from 1964 until his death.

ANDREW KEITH JACK was born in 1885. He obtained his MSc degree at Melbourne University, specializing in chemistry. He later became a Fellow of the Royal Institute of Chemistry of Great Britain and of the Royal Australian Chemical Institute. He was a member of Shackleton's Antarctic Expedition in 1914. On return to Melbourne in 1916 he joined the staff of the Commonwealth Explosives Factory at Maribyrnong. After a career in explosives work, he became the secretary of the Operational Safety Committee in the Department of Supply and held that position until his retirement in 1950. He was an associate member of the Royal Society of Victoria from 1913 until 1960, and a full member until his death on 26 September 1966.

ERNST MATTHAEI was born in Trier, Germany, in 1904. He studied in the classical School of Optics at the University of Jena, and was awarded the Diplom-Optiker, 1925. He came to Australia as a representative for Carl Zeiss, Jena, 1929, and joined the staff of Melbourne University 1939, after the outbreak of war. In 1950 he inaugurated for postgraduate students a course in Microscopy based on his own studies in Germany. This was extremely well received, and later was extended, at the request of the University, to embrace shorter courses for undergraduates in the various biological sciences. Similar courses in English-speaking universities overseas, and by the Royal Microscopical Society, London, have only recently been instituted. His knowledge of the optical microscope was unique in Australia, and he was widely consulted on optical problems. In addition, he was a man of great personal charm. He joined the Royal Society of Victoria in 1959, and died 15 July 1966.

## TREASURER'S REPORT

*Summary for Year ended 31 December 1966*

Balance from 1965 . . . . .	\$2,137.01
Total Receipts . . . . .	13,124.76
	<hr/>
	\$15,261.77
Total Payments . . . . .	9,209.34
	<hr/>
Balance brought forward . . . . .	\$6,052.43
	<hr/>

*Investments held as at 31 December 1966*

Bitumen and Oil	
8% Registered Unsecured Notes . . . . .	\$200.00
Industrial Acceptance Corporation	
7% Registered Unsecured Notes . . . . .	8,000.00
Finanee Corporation of Aust. Limited	
6½% Registered Unsecured Notes . . . . .	1,800.00
Ford Motor Company of Australia	
7% Debenture Stock . . . . .	2,000.00
	<hr/>
	\$12,000.00
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## FINANCIAL STATEMENT FOR YEAR ENDED 31 DECEMBER 1966

RECEIPTS		PAYMENTS	
Balance brought forward as at 1 January 1966 ..	\$2,137.00	Salaries—	
Subscriptions .....	3,405.99	Assistant Editor .....	\$63.00
Sale of Publications .....	1,022.26	Assistant Librarian .....	427.93
Interest—		Clerical Assistance .....	399.91
Investments .....	\$834.43	Hall Keeper .....	528.00
Interest from National Bank .....	90.79	Editorial Petty Cash .....	10.00
	<u>925.22</u>		<u>\$1,428.84</u>
Benefactions .....	555.00	Expenses of Visit, Professor K. Bullen .....	64.55
Grants and Donations—		Repairs and Maintenance .....	356.20
University of Melbourne .....	\$805.00	Rates and Taxes .....	149.40
University of New England .....	687.50	Electricity .....	630.05
University of New South Wales .....	156.00	Telephone .....	138.27
Commonwealth Publications Fund .....	500.00	Postage .....	226.03
Mrs. M. M. Moir .....	1,000.00	Publishing ( <i>Proceedings</i> Vol. 79 Part 1) .....	5,448.43
Crosbie Morrison Memorial Fund .....	20.00	Stationery .....	185.80
M. A. Ingham Trust .....	100.00	Expenses of Meetings .....	339.23
Victorian Dept. of Mines .....	200.00	Sundry Expenses—	
	<u>889.50</u>	Insurance .....	\$103.04
Rent .....	4,358.00	Addressograph .....	127.50
Hall Keeping Refunds .....	2,202.25	Refund Refreshments—	
Miscellaneous Refunds and Receipts—	<u>234.25</u>	Meeting cancelled .....	12.00
Telephone Account .....	\$5.35		<u>242.54</u>
College of Education .....	44.00	Balance as at 31 December 1966 .....	6,052.43
South British Ins. Co. ....	163.38	(Details of Cash Balance as at 31.12.66)	
Sundry (Postal Note) .....	0.30	Balance at Bank 31.12.1966 .....	\$6,035.77
	<u>213.03</u>	Add Cash received but not	
	208.76	in Bank .....	\$274.55
		Less Unpresented Cheques ..	257.89
			<u>16.66</u>
			<u>\$6,052.43</u>
	<u>\$15,261.77</u>		<u>\$15,261.77</u>

LIONEL ADAMS, *Hon. Treasurer*  
8 March 1967

Audited and found correct—  
S. M. WADHAM } *Hon.*  
R. R. GARRAN } *Auditors*  
8 March 1967



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